PROGRESS REPORTS

FROM

EXPERIMENT STATIONS

SEASON 1955-56

COTTON RESEARCH STATION
NAMULONGE, UGANDA

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COTTON RESEARCH STATION, NAMULONGE

PROGRESS REPORT FOR THE SEASON 1955-56

		Cotton	*Food Crops*
Sowing	...	June-August	February-April
Flowering	...	September-November	—
Reaping	...	December-March	May-August

Introduction

BY

SIR JOSEPH HUTCHINSON.

The Namulonge Advisory Board met on December 7th, 1955. Dr. E. W. Russell, Director of E.A.A.F.R.O., was welcomed on the occasion of his first attendance.

Among the distinguished visitors to the station during the year were H.E. the Governor and Lady Cohen; Lord de la Warr and Lord Hudson; Isebantu the Kyabazinga of Busoga; Sir Geoffrey and Lady Clay; the Principal of Wye Agricultural College; the Director of the National Institute of Agricultural Engineering, Wrest Park; the Professor of Horticulture, Reading University; the Professor of Chemistry, Queen Mary College, London; Monsieur M. C. Rossin of the Ministère France d'outre Mer; and Dr. E. B. Worthington. Among the groups of visitors were the members of the Working Party on Higher Education in East Africa, and parties from the C.C.T.A. Conference on the Mechanisation of Agriculture, the International Geographical Union Symposium held at Makerere College, and the Specialist Committee on Agricultural Botany.

Mr. P. D. Walton joined the staff of the plant breeding section in August 1955. Mr. Walton was a Corporation student in 1950 and then joined the Sudan Ministry of Agriculture as plant breeder (other crops). After spending the cotton season at Namulonge, he left for Serere on April 26th, 1956, where he will take over the cotton breeding work for the Eastern Province of Uganda.

Mr. D. E. B. Kibukamusoke returned to the plant breeding section after two years' absence at Cambridge on a C.D. and W. scholarship. He resumed his statistical work under Mr. Manning and took over the lint testing work from Mr. Evenson.

Namulonge sustained a heavy loss in the resignation of Mr. Evenson on health grounds. Though the lint testing is well established, and continues undiminished under Mr. Kibukamusoke, the more

fundamental work on the physiology of crop development and its effect on quality must await the arrival of his replacement.*

Mr. D. Ocheng is to be congratulated on the award of an overseas scholarship. He resigned in September 1955 to go to Aberystwyth to read Agricultural Economics.

Mr. B. J. S. Lee was appointed to a studentship in plant breeding tenable at Namulonge, and arrived in September 1955. Mr. H. M. Parker spent three months at Namulonge from September to December 1955 in the plant pathology section before going to Northern Nigeria as plant pathologist on the Corporation staff.

Mr. Stephens continued his farm classes for Makerere agriculture students. The Makerere herd remained at Namulonge throughout the year.

The following visits were paid by members of the staff:

Sir Joseph Hutchinson to Muguga (Kenya) to attend the meeting of the East African Agricultural and Fisheries Research Council.

Dr. Wickens to the Belgian Congo at the invitation of Cotonco to advise on bacterial blight problems.

Mr. Le Mare to Muguga (Kenya).

Mr Logan to Ukiriguru (Tanganyika) and Nyanza Province (Kenya).

Mr. Prentice to Muguga (Kenya) and Nyanza Province (Kenya).

Mr. Walton and Mr. Lee to Nyanza Province (Kenya).

Mr. Coaker to Nairobi (Kenya) for the Specialist Committee on Insecticides, Nyanza Province (Kenya), and the Tanganyika Agricultural Corporation, Urambo (Tanganyika).

Mr. Le Mare's comparative work on soil chemistry at Namulonge and Ukiriguru will be greatly facilitated by the appointment to Ukiriguru of Mr. A. M. Kabaara in January 1956 on graduating from Makerere College with his B.Sc.(London).

A conference of research officers of the Corporation was held at Namulonge in October 1955, and was attended by members of the staff from Nigeria, Tanganyika, and Kenya. The conference was fortunate in having Dr. G. D. H. Bell, Director of the Plant Breeding Institute, Cambridge, as a guest.

The Uganda Crop

BY

SIR JOSEPH HUTCHINSON AND H. L. MANNING.

The season was within the normal range of expectation, with a rather more pronounced mid year dry season than the average. At

*Mr. J. E. Dale from King's College, London, has been appointed, and is expected to take up his appointment in September 1956.

Namulonge there was a fall of 1·3 ins. of rain on June 17th, and thereafter there was no rain sufficient for good planting conditions until the last week in August. These rather dry conditions were general, and unfortunately considerably reduced the effect of an intensive campaign by the Agricultural Department for early planting.

Plantings to the end of July were below those of the previous year. Those in August were up by 120,000 acres, and those in September were only half those of 1954. Thus the average planting date was not quite so good as in the previous year, and the total acreage was down by 140,000 acres. On planting date and acreage a crop estimate of 342,000 bales was made in November 1955, compared with one of 360,000 made in November 1954 for the 1954-5 crop. In December the Department of Agriculture estimated 365,000 bales. The growing season was satisfactory, and there was no reason at any time to anticipate any considerable departure from the estimate based on planting date and acreage. The crop actually realised about 360,000 bales.

The Farm

BY

A. L. STEPHENS.

The area of the farm cleared and under control has been increased by 96 acres arable and 60 acres permanent pasture, bringing the total acreage under control up to 847, made up as follows:

	acres
Cropped in 1955-56	306
Grass ley	123
Cleared in 1955-56 but not cropped	37
Paths	50
	——516
Paddocks	176
Housing area (partly grazed)	60
	——236
Housing, laboratory and steading areas (not grazed) ...	55
Gum plantation	40
Total area under control	847

The Nalumuli and Kirimantungo sections of the farm are now complete. The former consists of six blocks of between 25 and 30 acres each exclusive of roads and paths, three being under crops and the other three under grass leys; and the latter of nine blocks of $3\frac{1}{2}$ to 4 acres each, five blocks being under crops and the other four under grass leys.

In the Ginnery farm section, which is to consist of six blocks of about 30 acres each, one block was down to ley; three were under crop, and a fifth has been cleared ready for cropping. The Sendusu section remained static with eight out of the proposed nine blocks in use, two under leys and six under crops.

The current development programme will be completed with the clearing of the ninth block on Sendusu and the sixth on the Ginnery farm. As the layout of the farms is so near completion, it was considered worth while to take advantage of the presence of a Hunting Aerosurveys plane at Entebbe to have an aerial survey made of the Station.

The first rains crops are harvested too late in the year for the 1956 crops to be recorded in a report covering a year from June 1st to May 31st. Data are, therefore, given below for acreages cropped in the first rains of 1955 and for the 1955-56 cotton season.

First rains crops (Planted Feb.-Apr. 1955)		Second rains crops (Planted June-Aug. 1955)		Long term crops	
	acres		*acres*		*acres*
Maize	72	Maize	9	Sweet potatoes	24
Beans	12	Beans	52	Cassava	51
Groundnuts	29	Cotton	107	Cover crops (for seed)	2
Sunflower	13	Sunflower	3	Bananas	1
		Soya beans	6		

The yields per acre of the principal farm crops, excluding experimental and breeding plots, are shown in Table 1.

TABLE 1.

YIELDS OF PRINCIPAL CROPS IN LB. PER ACRE.

Crop	*Acreage*	*Conditions*	*Yield (lb. per acre)**
Cassava		14 months old	12,000
		16 months old	13,400
		26 months old	17,200
Sunflower			650
Groundnuts			640
Beans			600
Maize K8	28	January sown	2,490
Muratha	5	February sown	2,110
Ulu	11	late February sown	1,910
Ulu	11	late April sown	450
Cotton NC55/Q	21	June sown after maize	1,180
NC55	8	June sown after beans	1,150
NC55	8	June sown after potatoes	810
NC55	7	August sown after groundnuts	570

* Groundnuts as unshelled nuts.
Maize as dry grain.
Cotton as seed cotton.

The only crops which gave poor yields were groundnuts, of which the stand was very poor; sunflower which, though potentially a heavy crop, suffered greatly from the depredations of birds, both weavers and doves; and the late sown Ulu maize which germinated poorly and failed to develop properly in the between-seasons weather.

The NC55 cotton grown after sweet potatoes did not yield as well as that on adjacent strips sown on the same day after beans, probably because the land in the former case had been poached by cattle which were used to graze off the potato tops when the land was too wet.

The cotton crop was the biggest that the station has yet produced, 54 bales of BP52 lint having been sold to the Lint Marketing Board, and the equivalent of 11 bales of mixed varieties sold locally as scrap.

The most satisfactory feature of the year's cropping was the combined yield of maize and cotton on the 6th clearing of Nalumuli, where the Namulonge time-saving system was used of planting the cotton on the same ridges that the maize had come off. The early sown K8 maize yielded 2,490 lb. of dry grain per acre, while the cotton, NC55/Q, gave 1,180 lb. of seed cotton per acre on a field of 21 acres. Another pleasing feature was that in a year when the quality of the Buganda cotton crop was poor, the Namulonge farm averaged only 2·1% dirty and stained cotton for NC55/Q, 2·8% for early sown NC55 and 3·5% for late sown NC55.

The Namulonge herd of cattle has increased by seventy-seven head, bringing the total up to 316. This increase is composed of eighty-one births plus thirty-eight cattle (culls) transferred into the herd from the Makerere herd as a payment for looking after the latter, less forty-two head either killed for meat or died from other causes. In addition Namulonge has continued to look after the Makerere herd, which now numbers sixty-two.

The calf mortality, though much lower than during the previous year, is still high. Of the twenty-one deaths occurring during the year more than half were due to East Coast Fever (positive blood slides) or complications arising therefrom.

Agricultural Meteorology

BY

H. L. MANNING AND H. G. FARBROTHER.

Summarized meteorological data are presented in Table 2 in the now standardised seasonal arrangement, firstly for the complete cotton season from June to January and, secondly, for the food crop season February to May, 1956.

TABLE 2.

SUMMARY OF METEOROLOGICAL DATA FOR 1955-6.

Month	*Rainfall*	*Evaporation*		*Relative Humidity*		*Hours*	*Air Temperature*	
	Ins. (Days)	*48" Pan*	*Recorder*	*a.m.*	*p.m.*	*Sunshine*	*Max.*	*Min.*
June 1955	3·03 (7)	5·13	4·18	83·8	55·7	7·1	81·5	60·2
July	0·88 (11)	4·68	4·28	81·7	58·9	6·0	81·2	59·9
Aug.	3·88 (14)	4·23	3·64	84·7	64·0	4·8	83·3	60·8
Sept.	3·73 (16)	4·30	3·66	84·0	65·2	5·3	80·9	60·5
Oct.	4·78 (15)	5·36	4·27	76·5	59·2	6·3	83·1	60·3
Nov.	1·61 (13)	5·08	4·58	75·9	52·3	6·6	83·8	60·6
Dec.	4·24 (16)	5·25	4·57	81·5	54·1	6·7	82·6	60·3
Jan. 1956	3·76 (11)	5·70	4·55	81·0	50·1	7·1	81·9	59·2
Sums	25·91 (103)	39·73	33·73	—	—	—	—	—
Means	—	4·97	4·22	81·1	57·4	6·2	82·3	60·2
Feb.	1·49 (4)	4·89	4·20	86·6	53·9	6·2	83·2	59·0
Mar.	3·73 (11)	6·88	5·44	78·2	49·4	6·8	86·3	61·4
April	7·77 (21)	4·74	3·35	85·4	65·5	5·0	81·2	61·9
May	3·73 (19)	4·43	3·39	85·6	66·8	5·1	80·4	61·4
Sums	16·72 (55)	20·94	16·38	—	—	—	—	—
Means	—	5·23	4·10	84·0	58·9	5·8	82·8	60·9
General								
Sums	42·63 (158)	60·67	50·11	—	—	—	—	—
Means	—	—	—	82·1	57·9	6·1	82·4	60·4

While the absolute total of nearly 26 inches of rainfall for the cotton season may appear to be satisfactory, the actual distribution was far from ideal during part of the vulnerable period of fruiting development. Favourable conditions for growth and early development prevailed up to the first half of October. At this date very high yields were expected for early sown cotton. Thereafter, a sustained period of low rainfall, which continued through November, caused a considerable loss of young bolls. The dry period, which is partly obscured in Table 2 because of the monthly grouping, had a marked effect on further crop development. This view is supported by data on supplementary irrigation (reported later under Plant Physiology) where soil moisture deficits during this critical period were experimentally reduced. Here overall seed cotton yield increments of nearly 50% (1,125 lb. to 1,650 lb. per acre) were obtained. These same experiments indicated, moreover, that the very considerable amounts of rainfall during December and January were then too late to contribute to further crop production. In consequence it may be said that the rainfall effective for crop production was little more than 18 inches out of 26 inches received. This illustrates clearly the pitfalls involved in estimating the adequacy of rainfall to meet crop water requirements on the basis of over-all seasonal totals.

Seed cotton yields of the improved Namulonge stocks of BP52 are summarized in Table 3 for the past six seasons. The characteristic decline in yield of July and, more particularly, August sowings is clearly shown in both favourable and unfavourable seasons. Yields from the June sowings during the 1955-6 season are shown to be the second highest so far obtained.

TABLE 3.

LARGE SCALE YIELDS OF BP52 STRAINS.

YIELDS PER ACRE OF SEED COTTON—ACREAGE IN BRACKETS.

Season	*June*		*July*		*August*	
	1-15	*16-30*	*1-15*	*16-31*	*1-15*	*16-31*
1950-1	961 (3·0)	—	582 (3·8)	575 (5·4)	474 (3·4)	—
1951-2	1150 (1·1)	1163 (5·4)	1072 (0·4)	1145 (1·2)	831 (1·7)	772 (1·4)
1952-3	920 (3·9)	983 (3·2)	1015 (3·8)	679 (1·4)	562 (7·7)	277 (5·2)
1953-4	965 (9·8)	975 (8·4)	—	—	756 (7·0)	—
1954-5	380 (9·5)	429 (19·3)	312 (4·0)	341 (9·4)	281 (2·7)	161 (4·5)
1955-6	898 (3·4)	1095 (36·7)	—	—	581 (9·0)	362 (1·8)

CROP HUSBANDRY

BY

A. N. PRENTICE.

General.

Cotton yields generally were satisfactory provided the crops were planted and established early in June. Good moisture conditions for

planting were not experienced from the third week of June until well into August, but the early June plantings thrived over the dry period; planting before, say, mid-June would seem a good and safe practice, though it may not always be convenient.

Time of Planting and Spacing.

Apart from the comparative failure of the "second early" planting, owing to delayed establishment, the response of cotton to time of planting was markedly in favour of early planting as usual. The large time of planting and spacing trial gave the seed cotton yields set out in Table 4.

TABLE 4.

YIELDS OF SEED COTTON (LB./ACRE) IN A PLANTING DATE AND SPACING TRIAL. PLANTINGS AT 3 WEEK INTERVALS.

Spacing	*13.6.55*	*4.7.55*	*28.7.55*	*15.8.55*	*Mean*
3′ × 2′	990	420	485	300	549
3′ × 1½′	1085	625	430	340	620
3′ × 1′	1090	660	555	405	677
3′ × ½′	1020	720	505	405	662
Mean	1046	606	494	362	

L.S.D. (P = ·05) for date means = 148 pounds per acre and for spacing means = 47 pounds. No significant date × spacing interaction.

Rotation Trials.

In the bigger of two crop succession trials there was no sign of any preceding treatment effect on the cotton indicator crop. By contrast, the two planting dates used in this trial, 15th June and 15th July, gave rise to a vast difference in yields.

Preceding crop:	*Seed cotton, lb. per acre.*	
	Early	*Late*
Bare fallow	991	449
Sunnhemp (cut as mulch)	959	402
Beans	964	—
Groundnuts	—	401
Maize	—	407

The preceding crops, i.e., those of the first rains of 1955, were just mediocre. Maize planted at the end of February yielded 1,540 lb. per acre of dry grain, but this same K8 variety planted a month earlier as a farm bulk (see Farm report) had yielded 2,500 lb. per acre, and evidence of the benefit of planting maize very early in the first rains

continues to grow. Beans yielded 690 lb. per acre—fair—and groundnuts an apparent 580 lb. per acre of shelled nuts, but the loss by theft between digging and shelling was probably very heavy.

A crop succession trial with maize as the indicator crop in both rains has shown no treatment effects so far. Maize sometimes yields as well in the second rains of the year as in the first (the first rains are the more commonly used for maize in the district, perhaps because of their greater amount and reliability). Yields in this trial from continuous maize, twice a year, are as good as from maize after non-maize. Cotton planted as late as 16th August on this site yielded at the rate of 474 lb. seed cotton to the acre.

In another trial in the rotation series (3 replications only), cotton interplanted early in maize showed no obvious depression of maize yield and a considerable measure of early planting benefit to the cotton, i.e., 830 lb. per acre from the interplanted cotton compared with 910 lb. from early not interplanted, and 420 lb. from late not interplanted.

In a trial intended to test the "best" crop to follow a one-year *Chloris gayana* ley, the indicator crops suffered heavy damage from monkeys, cattle and birds but at least showed that cotton did not suffer from being planted only eight weeks after the ploughing-under of the grass. Growth was noticeably better after grass than after continuous arable cropping, especially in the early stages, and this was reflected in the seed cotton yields, which averaged 1,036 and 512 lb. per acre respectively.

The main trial in the rotation group, although planted to its cotton indicator crop on 20th June, suffered from a patchy stand. The yield of the control treatment, continuous arable, beans followed by cotton, was 930 lb. seed cotton per acre, and of cotton following three year grass with a bean crop intervening was 1,060 lb., and these crude yields were typical of all the early planted treatments. Cotton following maize and therefore planted late, on 30th July, had a perfect stand from the beginning but yielded only 445 lb. per acre.

Cultivation Methods.

The trial containing the three treatments, flat, tie-ridged, and flat-planted but ridged a month after planting, was under sunnhemp for seed in the first part of the year and under soya beans in the second rains. The overall average for the field of nearly four acres was 404 lb. sunnhemp seed per acre and approximately 500 lb. soya bean seed. Under sunnhemp, flat was outyielded by ridged by some 16%, and this was reversed almost exactly under soya beans. Both differences were of doubtful significance, but assuming they were in fact true, stand again possibly influenced the results. One benefit of ridging after planting is that establishment is as good as on the flat.

Many ad hoc tests of weed-killers to control *Digitaria scalarum* were carried out. Sodium trichloroacetate or TCA, and "Dalapon", the sodium salt of dichloropropionic acid, are the only two of much account among those tried so far. These, at the concentrations needed to kill the grass, have a lengthy residual toxic effect, no appreciable selectivity, and are expensive, but as they are no more expensive than eradication by hand labour they may have a part to play in Buganda and other areas where the weed is serious.

Crop Botany.

In cotton the sorting out of types derived from crosses and backcrosses of Tanganyika 7/367 × Albar 51 continues. Drastic elimination in backcrosses resulted from a second inoculation of plants which had survived the first inoculation of *X. malvacearum* in the field. In trials against BP52/NC54, the best of the backcrosses did as well as but no better than NC54 this year.

In maize, Namulonge was one of the eleven centres of a co-operative maize trial run by the Specialist Committee on Agricultural Botany of E.A.A.F.R.O., and supplied some of the varieties in the trial. Most varieties tested did well on their home ground and badly at distant centres, as might have been expected. Rongai Yellow from Kenya, however, broke through this generalization by yielding well at many centres including Namulonge, and this variety is being watched for possible use here.

Breeding work has as an immediate object the production of a quick-maturing large-grained yellow dent maize for the locality. Hybrid maize, inter-varietal crosses, and maize of various degrees of inbreeding are produced, and some interesting comparisons are emerging in trials.

Helminthosporium turcicum leaf disease was particularly severe on the second rains maize, and the early maturing K8 was one of the worst hit. The variety Muratha showed considerable resistance. Bird-damage was also of unprecedented severity on maize in the second rains.

Soil Chemistry.

BY

P. H. LE MARE.

Two field experiments which form part of the communal experiment at Nalumuli and Sendusu (see Progress Report for 1954-55, p. 15) were continued this year to obtain information on residual effects of nitrogen and phosphorus fertilizers. Details of the designs and treatments in 1955 were as follows:

Design: 2^4 factorial in four blocks of eight plots each, the four factor interaction being confounded with blocks.

Nitrogen: N_1: None and 1·0 cwt. N per acre applied in 1954.

N_2: None and 1·0 cwt. N per acre as sulphate of ammonia applied in two doses, viz. $\frac{1}{3}$ cwt. applied on 6 September and $\frac{2}{3}$ cwt. on 14 October 1955. The fertilizer was applied on the ridge in drills between the plants.

Phosphorus: P_1: None and 0·5 cwt. P per acre applied in 1954.

P_2: None and 0·5 cwt. P per acre applied in 1955 as triple superphosphate placed before planting in two bands approximately 2 inches below and $3\frac{1}{2}$ inches to the side of the seed.

Date of planting: 20 June 1955. Spacing: 3 feet × 1 foot, 2 plants per hole. The mean yields, main effects and two factor interactions are presented in Table 5.

Table 5.

Mean yield, main effects and interactions, lb. seed cotton per acre, Nalumuli and Sendusu.

		Nalumuli	*Sendusu*
Mean yield		1023	1271
Main effects			
N_1		176	38
N_2		−32	−22
P_1		13	117
P_2		80	114
Interactions			
N_1N_2		−42	1
N_1P_1		−26	− 1
N_1P_2		9	−39
N_2P_1		− 3	−10
N_2P_2		3	31
P_1P_2		−32	−31
S.E. Main effects and interactions		±52·5	±59·1
Sig. effects and interactions	5%	113	127
	1%	156	176

In both experiments there were small responses to phosphate applied to the current cotton crop and at Sendusu to phosphate applied the previous year also. As one would expect, the P_1 P_2 interaction was negative, but its low value suggests that residual and directly applied P were acting independently. At Sendusu P_1 and P_2 alone each increased yield by about 150 lb.; together they increased yield by 230 lb. If this effect is real, it suggests that the method of placement of the phosphate to the current crop was not satisfactory; a proportion placed fairly deeply below the seed with the rest placed as a starter dose near the seed might have been better. There was dry weather

soon after planting and again in October-November. Under such conditions fertilizer placed near the surface may have been unavailable for a considerable period, owing to dry soil conditions around it.

In both these experiments nearly the whole of the phosphate effect was obtained in the first pick, as is shown by the following figures which give cumulative totals for the picks.

	Nalumuli				*Sendusu*			
No. of picks	1	2	3	4	1	2	3	4
Yield no P	406	666	908	960	360	846	1088	1140
Response to								
P_1	18	30	45	45	131	188	152	148
P_2	129	140	128	112	156	193	155	145
P_1+P_2	27	72	93	93	199	285	237	231
Sig. response								
5%	72	113	148	160	148	201	186	180

The effect of phosphate in promoting early production of seed cotton is interesting and whilst this effect is well known it is surprising that later pickings should not have been somewhat increased by the presence of P.

Sulphate of ammonia increased yield in the experiment at Nalumuli only. The increase of 176 lb. seed cotton per acre was produced by sulphate of ammonia applied to the previous cotton crop but there was no response to sulphate of ammonia applied directly to the current crop. In the previous year yields were low and there was no response to any fertilizer. During the first rain season of 1955 maize was grown on the plots and this was uprooted and laid as a mulch before maturing to permit timely planting of cotton. It is possible that the residual nitrogen was at a deeper level, or was otherwise more suitably distributed in the soil where moisture was available during the dry period of October-November, a period when nitrogen would be in high demand by the crop, whereas the ammonium sulphate applied directly to the crop itself was still in the dry surface soil. The possibility of the effect being due to sulphur cannot be ignored but as the sulphate ion is more mobile in the soil than the ammonium ion the effect is more likely to be due to nitrogen.

Both of these experiments were on land which since 1950 has been cropped with cotton in the second rains, following maize uprooted and laid as mulch in the first rains.

In recent years there has been much discussion of the possibility that East African soils are sulphur deficient. An experiment was laid down to determine the effect of sulphur, applied as gypsum, at Namulonge.

Site: Sendusu. Land broken from bush fallow and cropped twice a year since 1952.

Design: 2^4 factorial in four blocks of eight plots each, the four factor interaction being confounded with blocks.

Nitrogen: A basal dressing of 0·7 cwt. N per acre was given; two different fertilizers, ammonium nitrate and nitrate of soda, were compared.

Phosphorus: None and 0·5 cwt. P per acre as triple superphosphate.

Potassium: None and 1·0 cwt. K per acre as muriate of potash.

Sulphur: None and 1·0 cwt. S per acre as gypsum.

The P, K and S fertilizers were mixed and placed in two bands approximately 2 inches below and 3½ inches to the side of the seed one week before planting. The nitrogen fertilizers were applied as a top dressing along the rows of cotton on 22 August.

Planting date: 17 June 1955. Spacing: 3 feet × 1 foot, 2 plants per hole.

In this experiment the final yield was 1,289 lb. seed cotton per acre and no significant effects were caused by any of the treatments. The yield of the adjoining non-experimental cotton was 1,250 lb. per acre indicating that the effect of nitrogen which was given over the whole experiment was small. The final yield, main effects and differential responses, in lb. seed cotton per acre, are given in Table 6.

Table 6.

Mean yield 1289 lb. seed cotton per acre.

Factor	Main effect	Response with: Amm. Nitrate	Sodium Nitrate	Triple Super (P) abs.	Triple Super (P) pres.	Mur. Potash (K) abs.	Mur. Potash (K) pres.	Gypsum (S) abs.	Gypsum (S) pres.
Sod. Nitr.-Amm. Nitr.	30	—	—	−18	78	55	5	53	7
P_1-P_0	49	1	97	—	—	57	41	6	92
K_1-K_0	31	56	6	39	23	—	—	93	−31
S_1-S_0	−12	11	−35	−55	31	50	−74	—	—
SE	±44·1			±62·4					
Sig. response 5%	95			134					

In the first pick, which amounted to about one-third of the final crop, sodium nitrate was significantly superior to ammonium nitrate where potassium had not been given, and there was a small improvement due to potassium in the presence of ammonium nitrate, though not where sodium nitrate had been given.

These effects, although small and of no present economic importance, are worthy of note in that they may be indicative of possible future

effects when the soil has been heavily cropped for a longer period. They are also interesting in relation to results reported from other cotton growing areas, notably America, where potassium and sodium promote the more efficient use of water and early fruiting and boll maturity. Sodium is of little value if potassium is adequate but it can to some extent be a substitute for potassium if the latter is deficient.

Further information is available on the question of sulphur deficiency from an experiment at Sendusu first laid down to cotton in 1953 and followed by maize in the first rains and by groundnuts in the second rains of 1954. The results for cotton were given in the Progress Report for 1953-4 and for maize in the Report for 1954-5. The yield of groundnuts was about 1,300 lb. nuts in shell. There was no response to triple superphosphate applied to the groundnut crop before planting nor to residual phosphorus. Sulphate of ammonia was not applied to the groundnut crop itself, but there was no residual effect of ammonium sulphate, which had been applied at 5 cwt. per acre to the cotton crop and 2½ cwt. per acre to the maize crop. A response to nitrogen is not likely with groundnuts but if sulphur was deficient a response might have been obtained, since a total of 200 lb. per acre of sulphur, as ammonium sulphate, had been applied during the previous 18 months. Both previous crops gave responses to sulphate of ammonia, the maize giving a response to residual as well as to directly applied sulphate of ammonia. Thus only the non-leguminous crops responded, suggesting that the effect is due to nitrogen and not to sulphur.

In past experiments to determine the effect of nitrogen and phosphatic fertilizers on cotton, plant populations have not exceeded about 20,000 plants per acre. An experiment was laid down with cotton to determine the effect of N and P over a wide range of populations.

Treatments: Populations: 14·5, 29·0, 43·5 and 58·0 thousand plants per acre. Rows were 3 feet apart and plants were spaced 24, 12, 8 and 6 inches within the rows. There were two plants per hole.

Phosphorus: None and 0·5 cwt. P per acre as triple superphosphate applied before planting in two bands approximately 2 inches below and 3½ inches to the side of the seed.

Nitrogen: None and 1·0 cwt. N per acre as sulphate of ammonia, applied in three doses of ⅓ cwt. N on 19 August, 16 September and 12 October 1955.

Design: Five 4 × 4 lattice squares.

Planting date: 8th June 1955.

The experiment was on land which had grown five crops since the bush fallow was ploughed early in 1953. The final populations were about 15% below the planted population. There was no appreciable effect of any of the fertilizers. The optimum population was 29,000 plants per acre, which gave 1,000 lb. seed cotton per acre, 135 lb. more than the lowest population. The two highest populations gave yields only slightly below that of the optimum population. The final yield data in lb. seed cotton per acre are presented in Table 7.

Table 7.

Yield of seed cotton at four plant populations in the absence and presence of nitrogen and phosphorus, in lb. seed cotton per acre.

	Population planted				
	14·5	*29·0*	*43·5*	*58·0*	*Mean*
	±50·0 [a]				±25·0 [b]
N and P absent	836	977	993	917	931
N alone	844	958	915	913	908
P alone	917	1041	965	998	980
N + P	868	1029	1004	971	968
	±25·0 [b]				
Mean	866	1001	969	950	947
Significant difference:		*a*	*b*		
5%		144	72		
1%		194	97		

Sample plants were taken at monthly intervals for growth analysis. These analyses indicated that the number of bolls and buds held by the plant per unit area of land up to the end of October was increased by N and P at the higher populations but this effect was not maintained during the dry period in November when there was considerable shedding. The number of undamaged bolls carried per unit area at the end of November was 50% higher with the highest population than with the lowest population, but there were heavy boll losses later, and by the end of the season there was no effect of N or P. Dry weight of leaves and stems also increased with increasing population but, as the yield data show, this was finally effective only up to 29,000 plants per acre.

All the experiments so far described were planted in June. Two other experiments were planted in August, too late to obtain high yields. One of these, planted on 11th August, was laid down to determine the optimum population for late planted cotton in the absence of N and P and in the presence of both. The populations were 14·5, 29·0, 43·5

and 58·0. The lowest population gave the lowest yield, 315 lb. seed cotton. The three higher populations all gave significantly higher yields but did not differ significantly amongst themselves, their mean being almost 400 lb. seed cotton. At the highest population N and P together increased yield by 120 lb., the mean increase due to N and P for all populations being 70 lb. The detailed results are presented in Table 8.

Table 8.

Yield of seed cotton given by four plant populations in the absence of ammonium sulphate and triple superphosphate and in the presence of both. (lb. per acre)

	Population planted				
	14·5	*29·0*	*43·5*	*58·0*	*Mean*
	±29·9[a]				±14·9[c]
Without fertilizer	298	419	392	334	340
With N and P	331	336	423	457	407
	±21·1[b]				
	315	378	407	395	374
Significant difference:		*a*	*b*	*c*	
5%		87	61	43	
1%		117	82	58	

In an experiment planted on 10th August, plots to which mulch was first applied on 12th July and maintained throughout the season gave no greater final yield than plots planted without mulch. Nor was there any difference between two populations, 22,000 and 44,000 plants per acre. The yield without N or P was 610 lb. seed cotton. Nitrogen and phosphorus alone increased yield by 60 and 90 lb. respectively. There was no interaction and together they gave an increase of 150 lb.

Plant Physiology

by

H. G. Farbrother.

Growth and development data have again been taken on the communal experiment (Prog. Rep., 1954) cotton crops, both early and late. A total of 20 analyses of independent crops has now been reached since this study began in 1951 and work has begun on the statistical treatment of growth records in relation to meteorological data. The graphs of basic data showed a dependence on climatic circumstances

similar to that demonstrated in earlier seasons, and are therefore not presented again.

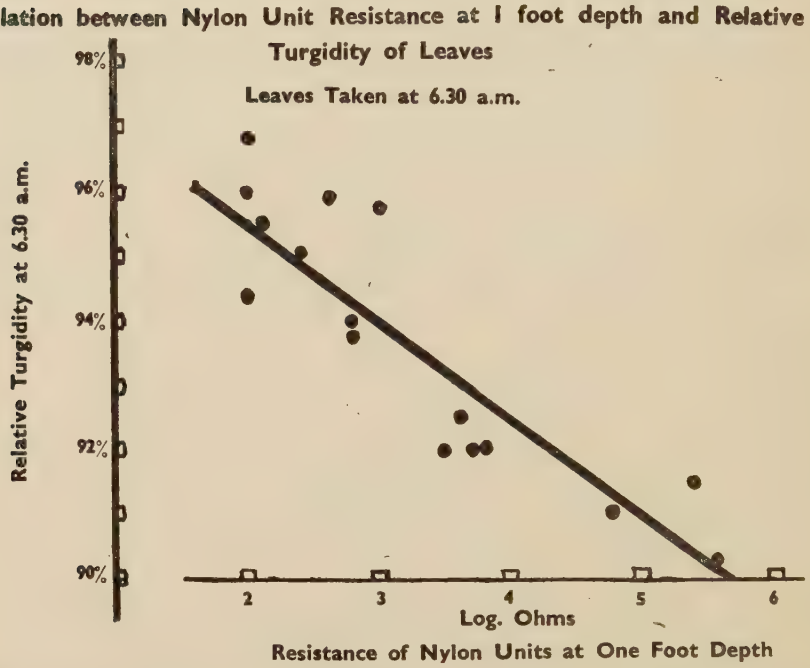
Attention was directed in the year under report to the use of growth analysis techniques for the study of crop water requirement. This, which is fundamental to all physiological studies of growth, was enormously facilitated by the provision of supplementary irrigation on three acres of land. The land commanded has been laid out to provide a total of 240 plots of 1/145 acre, each of which can be irrigated independently with measured quantities of water. The slope of the land, up to $2\frac{1}{2}\%$, and the high infiltration rate of the soil, limit the furrow length per plot to 20 feet; even so, 2 ins. waterings are preferable to 1 in. to ensure reasonable uniformity of percolation along the furrow length.

Day to day control of irrigation water has been based entirely on the use of Namulonge pattern nylon/stainless steel electrical resistance units. As many as five units per plot have been buried at one foot depth under the ridge, with additional units in selected plots down to a maximum of eight feet by 1 foot intervals. Only the one foot depth units have been used for water control purposes.

The relation of nylon unit resistance to soil moistures at the reproducible levels of wilting point and field capacity had been previously established (for large samples) at 5·0 log. ohms and 2·5 log. ohms respectively. Saturation of the soil, during irrigation for example, results in a decrease of resistance to approx. 2·0 log. ohms. This sensitivity of the nylon units to changes of moisture over the whole range met with in irrigation practice greatly simplifies the presentation of results; arithmetic averages of replicates can be used with greater safety than if units of the gypsum block type were used, which are insensitive over the wetter end of the range.

That the resistances recorded using these nylon units at 1 ft. depth are, in fact, related to the water stress experienced by the plant is shown by the relation between resistance in log. ohms and the water status of the cotton leaf as expressed by relative turgidity at 6.30 a.m. This relationship was studied by comparing relative turgidities at 6.30 a.m. with resistances recorded from nylon units placed in the top foot of soil, using both irrigated and rain fed plots. In order to avoid the complications arising when the top foot was dry (and resistance readings therefore stable) while relative turgidities were falling with increasing tension in the deeper layers of the soil, only data involving relative turgidities of 90 per cent. or more were considered. In Fig. 1 is given the relation between resistance recorded on nylon units at 1 ft. depth and the relative turgidity values at 6.30 a.m. averaged for 8 day periods, from cotton growing in the same plot.

FIGURE 1



The regression of relative turgidity on resistance in log. ohms was

$$\hat{Y} = 98{\cdot}8 - 1{\cdot}59X$$

$$R^2 = 0{\cdot}806$$

It will be seen that there is good agreement in spite of the variation introduced by the eight day grouping, and by ignoring the hysteresis effect involved when both wetting and drying cycles are included.

In this, the first season in which control of crop water supply was attempted, it was decided to give a 2 ins. irrigation when the average resistance of replicates reached 4·0 log. ohms. Evidence is presented below for the belief that a rather lower figure would have been better. The basic water relations data referring to one experimental block of 18 plots of BP52.7MB, planted on July 7th after an overall preplanting irrigation of 4 ins. are given in Figs. 2 and 3. "Control" was given no supplementary water after the preplanting irrigation and "Irrigation" a full supplement controlled by nylon units as explained above up to the time of first picking. Growth analyses were carried out on samples from the same plots and provide data on the development of the crop with and without irrigation. The relevant data for leaf area, plant weight and fruiting point totals are shown in Figs. 2 and 3. Data are presented for quarter-monthly periods.

At the head of each figure is given the water supply, from rain and from irrigation, to that treatment throughout the season. It will be seen that apart from the preplanting irrigation given to both treatments the supplementary irrigation supplied to the irrigated treatment was confined to the period beginning in the fourth quarter of October and ending in mid-December. Evaporation rates calculated from Piche evaporimeters hung in the open (Hutchinson and Farbrother, 1956) and expressed in inches per unit area are next given. The relation between the estimated open water surface evaporation on Penman's formulae, and the evaporation recorded from Piches in the open has been shown to be $\hat{Y}_{\text{Penman}} = 3{\cdot}368 + 0{\cdot}472 \times_{\text{Piche}}$ inches per month, with $R^2 = 0{\cdot}810$.

The third histogram gives an estimate of the water requirement of the crop throughout the season. This estimate was calculated using certain assumed relationships with evaporation from a Piche evaporimeter hung in the open in an attempt to provide a figure that would fit the observed facts of water use and crop development. Evaporation losses from an annual crop starting from seedlings are made up of two components, losses from the bare soil, which must diminish as the crop cover increases, and losses from the leaves. At the spacing used, 1,000 sq. ins. leaf area per plant is equivalent to 1 acre of leaf per acre of soil. The allowance for evaporation from bare soil was therefore reduced until it became nil when leaf area per plant reached 1,000 sq. ins. A generally accepted estimate for losses from bare soil is 0·3 of the estimated open water surface evaporation (Trumble, 1937). As a first approximation it is sufficient to take 0·3 $\times$ the Piche figure (E_p) as loss from bare soil while the leaf area is between 0 and 300 sq. ins. per plant, 0·2 $\times$ E_p while leaf area is between 300 and 600 sq. ins., and 0·1 $\times$ E_p while leaf area is between 600 and 1,000 sq. ins. Obviously, direct estimates of the variation of these losses with increasing leaf area are highly desirable, and it is proposed to attempt a measurement in the coming season. Evaporation from leaves was taken as

$$\frac{\text{leaf area (sq. ins.)} \times E_p}{1{,}000}$$

giving as a first approximation, evaporation equal to that from an equivalent area of wet paper surface as exposed in the Piche when the leaf area reaches 1 acre per acre. Thus the histogram for water requirements through the season was built up. Obviously the factors used are only preliminary, but they do provide an indication of the pattern of water needs in a developing crop, a pattern which is entirely different from that considered by Penman (1950) in his studies of water loss from a perennial, stable, close cut turf.

FIGURE 2

Water Balance and Growth Analysis Data on Irrigation Experiment

CONTROL PLOTS

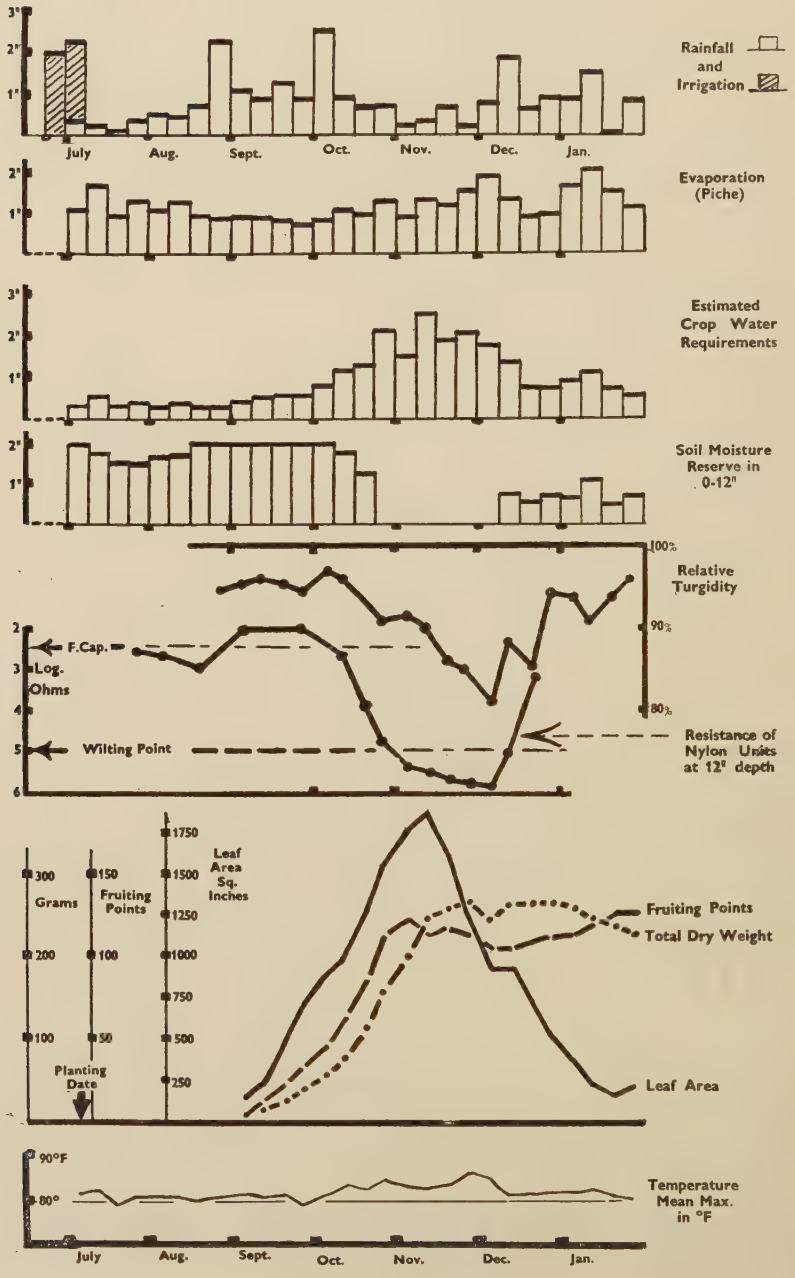
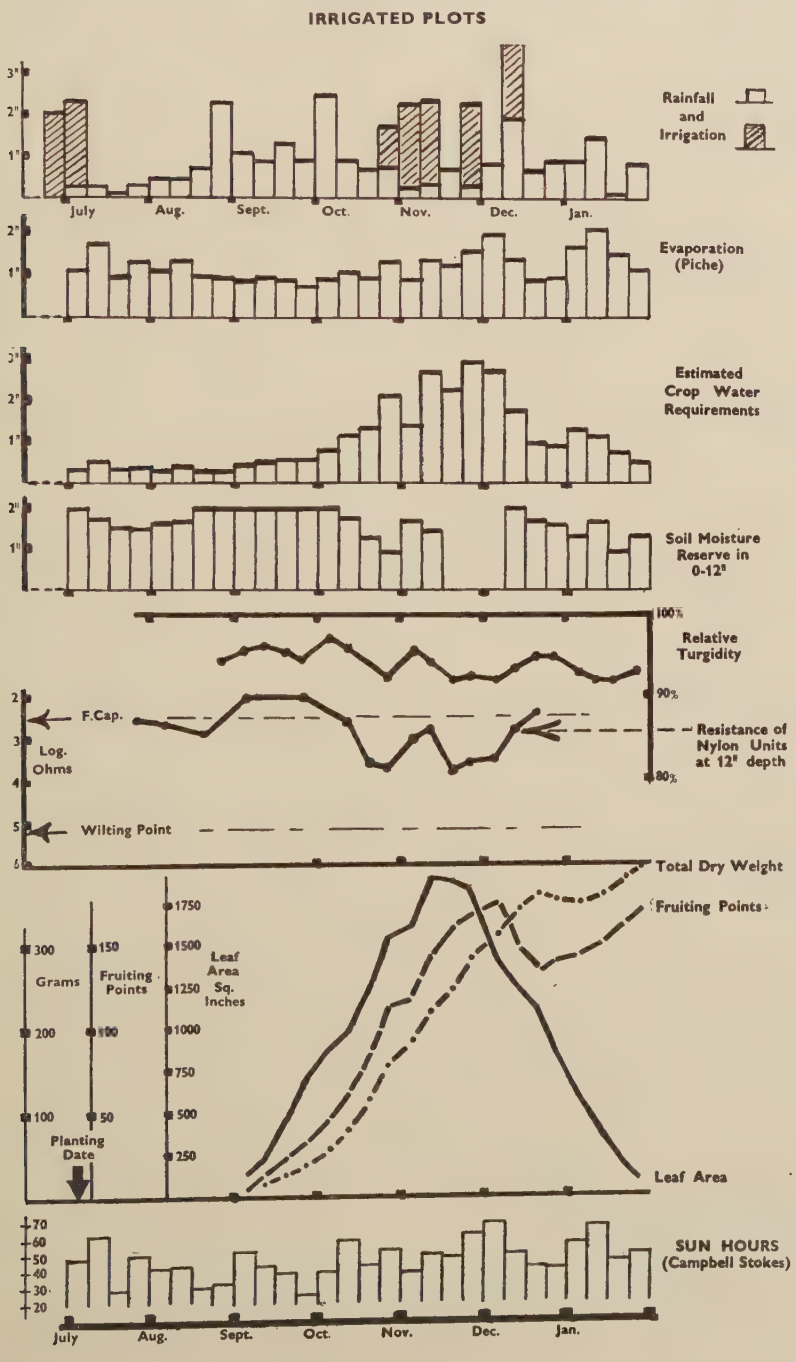


FIGURE 3

Water Balance and Growth Analysis Data on Irrigation Experiment



In the fourth histogram is given the amount of water calculated from the first and third histograms to be available in the top foot of soil. Between wilting point and field capacity the Namulonge soil holds approximately 2 ins. of water per foot. Assuming that the preplanting irrigation brought the top foot to field capacity, the crop started with 2 ins. of available water in the top foot. Thereafter the status of the top foot was estimated assuming that the rainfall or irrigation water first brought the top foot up to capacity, and the withdrawal of water by the plant reduced the top foot to wilting point before any important drain on the lower levels occurred. Though this is obviously an over-simplification, it will serve as a beginning. Two points should be noted. First, on the "control" treatment, the calculated reserves in the top foot were nil from the third week of October to the second week in December, which was the period of maximum crop water requirement. Secondly, the irrigation practice adopted was not quite critical enough to prevent depletion of the top foot reserves, which dropped to 1 in. in mid October, and to nil in the third week of November.

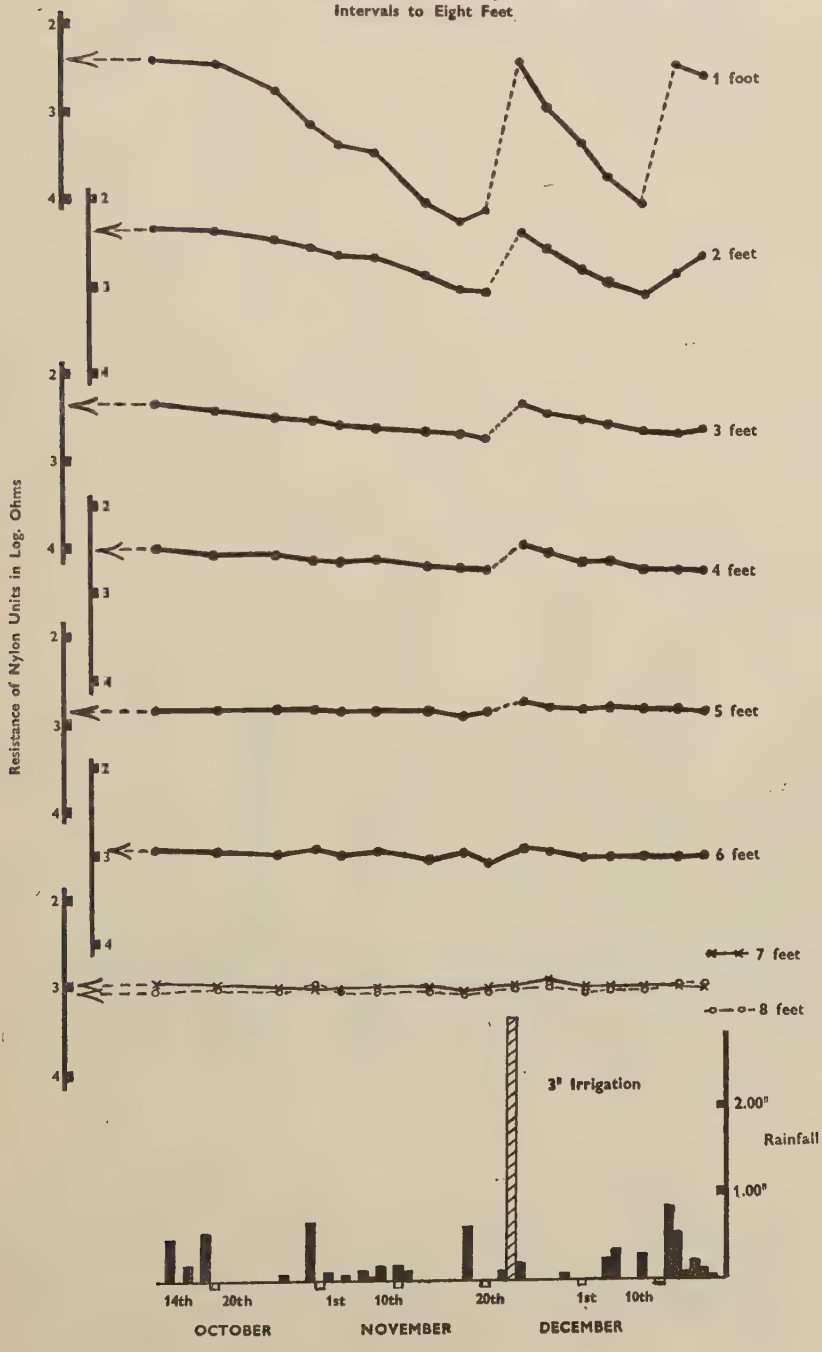
There follow curves of relative turgidity of leaf discs cut at 6.30 a.m. each day, and of resistance (in log. ohms) of nylon units at 1 ft. depth. It will be seen that both the relative turgidity curves and the curves of nylon unit resistance follow very closely the calculated depletion of the moisture reserves. It is thus apparent that the use of leaf area as well as an index of evaporation in the calculation of water requirement has resulted in an estimate that fits the data on the depletion of moisture reserves in the top foot in a way that would not be experienced if open water surface evaporation were used alone.

The growth analysis curves below give the leaf areas from which the crop water requirement was calculated, and the total number of fruiting points and the dry weight. Considering first dry weight, it will be seen that while the estimated crop water requirement was met without seriously reducing the soil moisture reserve in the top foot, growth continued exponentially. Shortly after the estimated reserves in the top foot dropped to nil, however, growth was checked, and in the unirrigated control, dry weight increase ceased. In the irrigated plots, where the water reserves were very soon replenished, growth continued but at a reduced rate. Fruiting point production reflected even more closely the depletion of the moisture reserve in the top foot. As soon as the calculated top foot reserves reached zero, increase in the number of fruiting points ceased. Some further growth occurred later in the irrigated plot, but the extra fruiting points contributed thereby were negligible.

At the time of cessation of fruiting point production, small bolls and all "matchhead" buds were shed. It is suggested that under the mesophytic rainfall conditions characteristic of Namulonge the onset

FIGURE 4

Resistance of Nylon Units (Log. Ohms) Against Time at One Foot Intervals to Eight Feet



of water stress of an intensity indicated by a calculated 2 ins. deficit in the top foot of soil terminates the formation of further bolls, and thus determines crop size. Moisture is, of course, tapped from deeper layers of the soil, but this is used to carry to maturity the crop already set, and is not adequate for any further additions. Moreover, from the behaviour of the irrigated plots it appears that the replenishment of the water supply does not result in further additions to the crop until that already set has been matured.

The pattern of water use from the soil in depth is illustrated by nylon unit resistance data from a plot in which the units were planted at 1 ft. intervals from 1 ft. to 8 ft. In Fig. 4 are given curves of resistance based on means of 14 units at each level up to 6 ft., means of 8 units at 7 ft. and 5 units at 8 ft. Rainfall data are given below. It will be seen that there was virtually no change in tension throughout the period below 4 ft. By far the greater part of all changes in moisture status was in the top foot.

The total yields of seed cotton picked from the 18 plots examined above are given below in lb. per acre. As plants from these plots were removed at weekly intervals for growth analysis samples, the original stand at germination and the final stand at last picking are given also. No adjustment has been made to the yield figures.

Control—

1,334 1,290 1,320 972 1,131 1,000 1,073 1,000 1,015 Av. 1,126

Irrigated—

1,537 1,508 1,305 1,638 1,522 2,132 1,551 1,812 1,885 Av. 1,654

Difference very highly significant

Original stand	Control 80%	Irrigated 75%
Final stand	Control 59%	Irrigated 56%

It will thus be seen that the effect of postponing the onset of water stress from October 24th to some time about a month later was to increase actual yields of seed cotton from 1,126 to 1,654, an increment of 528 lb. per acre, or a 47% response.

Entomology

BY

T. H. COAKER.

Studies of Crop Loss.

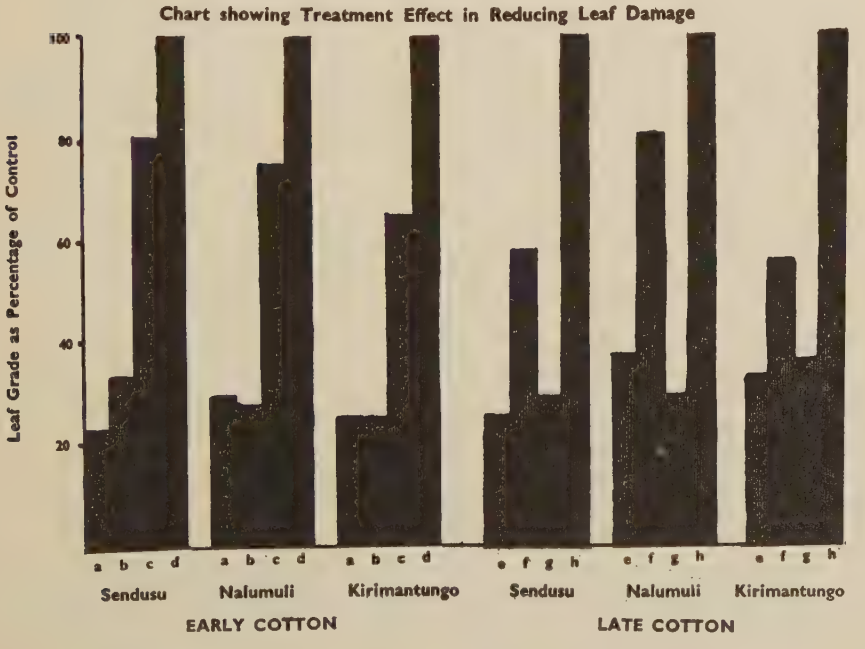
The experimental determination of crop loss was continued for a third and final year. The spray formulation used was the same as last year, being a mixture of DDT and Toxaphene in equal proportions applied once every 5 days as a 0·2% solution to runoff. Three spray treatments were used, together with a control for both early and late sown cotton, as shown.

Coverage	*Early sown*	*Late sown*
Complete season	a Aug.-Jan.	e Oct.-Feb.
Bulk of *Lygus* attack	b Aug.-mid Oct.	f Oct.
Bulk of bollworm attack	c Mid Sept.-Jan.	g Mid Oct.-Feb.
Control	d Control	h Control

During the three years sufficiently varied seasonal conditions have been experienced to illustrate the range of effects of the various pests on the crop. As in previous years single row plots were used, but owing to the bad germination of the cotton on the areas where the crop loss studies have been carried out in past years farm bulk cotton was utilised as near as possible to the sites previously used.

Lygus fluctuations measured by leaf damage on the two top fully open leaves showed little variation between localities (Fig. 5).

FIGURE 5



As in other years the peak damage occurred in late September and fell on an average to below the minimum measurable unit of leaf damage by the end of October. The leaf damage recorded on the late sown cotton gave no indication of *Lygus* migration from the nearby early sown cotton.

The most interesting result obtained from the analysis of fruiting point losses of the past and present seasons' data is the demonstration of a balance existing between the insect caused sheds and those with no visible signs of insect damage ("nil sheds"). The following figures, being an analysis of shed buds and bolls on early sown cotton from the three localities, serve to emphasise this point:

Analysis of Sheds on Early Sown Cotton.

Treatment.	*% Bollworm.*	*% Bug.*	*% Nil.*	*Total Sheds.*
a	0·6	2·1	97·3	1,674
b	0·5	3·6	95·9	1,647
c	2·0	3·6	94·4	1,580
d	16·9	17·4	65·7	1,605

As can be seen, the total number of sheds was very similar in all treatments, but the proportions were different. As was suggested in the last report, there appears to be some factor over-shadowing insect caused losses in determining the balance of yield.

Bollworms, of which *Heliothis armigera* Hbn. accounted for 70% of the population, were the most important insects causing damage to set bolls in the control treatments, but not where sprays were used. The following figures, again taken from early planted cotton as an average of the three localities, illustrate this point:

Locule Damage Caused by Bollworms and Sucking Bugs.
(*as % of all locules damaged*)

Treatment.	*Bollworms.*	*Bugs.*
a	11·6	77·7
b	33·8	59·3
c	24·3	68·7
d	68·9	28·9

A further analysis of split bolls showed a slight locality effect. Thus, at Sendusu the control treatment gave only 76% clean bolls in the early sown cotton, whereas the three sprayed treatments all gave approximately 90% clean cotton. At the other two localities the difference between sprayed and unsprayed was much less, the sprayed treatments giving some 96% clean cotton and the control treatments 93%. With late sown cotton, treatments e and g at Sendusu gave approximately 93% clean cotton, treatment f gave 74% and the control h gave 68%. At the other two localities treatments e and g gave 94% clean cotton and treatments f and h gave 81%.

Treatment yields at all three localities and for early and late sown cotton are shown in Table 9.

TABLE 9.

THE EFFECT OF INSECTICIDAL TREATMENT ON YIELD.

	EARLY			LATE		
Locality	*Treatment*	*Yield lb./acre*	*% of Control*	*Treatment*	*Yield lb./acre*	*% of Control*
Sendusu UP	Aug.-Jan.	961·7	116·9	Oct.-Feb.	608·2	156·2
	Aug.-mid Oct.	839·1	102·1	Oct.	469·0	120·5
	Mid Sept.-Jan.	1129·7	137·4	Mid Oct.-Feb.	619·5	159·1
	Control	822·0	100	Control	389·3	100
Kirimantungo NC55/Q	Aug.-Jan.	1218·9	125·2	Oct.-Feb.	499·3	106·9
	Aug.-mid Oct.	1201·0	123·3	Oct.	438·5	93·9
	Mid Sept.-Jan.	1091·2	112·0	Mid Oct.-Feb.	508·8	108·9
	Control	973·9	100	Control	466·8	100
Nalumuli NC55	Aug.-Jan.	1205·0	100·8	Oct.-Feb.	401·7	116·9
	Aug.-mid Oct.	1178·7	98·6	Oct.	301·1	87·7
	Mid Sept.-Jan.	1268·5	106·1	Mid Oct.-Feb.	361·7	105·3
	Control	1195·8	100	Control	343·5	100

The main conclusions to be drawn from the experiment under the conditions experienced at Namulonge during the past 3 seasons are:

(1) *Lygus* spp. and other Miridae present in the crop are not responsible for any serious loss of yield in early sown cotton. The length of the season makes possible recovery from early fruiting point loss. The effectiveness of this recovery is controlled by the climatic conditions. The retention of early fruiting points due to insecticidal control does, however, produce an earlier crop. Generally in late sown cotton, early fruiting point loss cannot be compensated by further growth and fruiting point production, and *Lygus* attack then causes crop loss.

(2) Bollworm damage can be inflicted on both the bud and young boll stages causing shedding, usually of less severity than that caused by *Lygus,* and on the larger set bolls. In early sown cotton, bud and young boll losses may be replaced; but large boll losses constitute a direct loss. However, the losses have not so far been large enough to justify further investigation into the economics of control measures.

(3) Differences between localities, even on the Namulonge farms, were greater than differences obtained between treatments. Since the localities in question are from one to three miles apart and variations are caused more by other environmental conditions than insect population differences, it cannot be too strongly stressed that all experiments conducted to determine the extent of losses due to insect pests should be repeated as widely as possible before any conclusions are drawn as to pest status.

Phytotoxicity. In the crop loss experiment phytotoxic symptoms were shown clearly after the second application of insecticide, and a trial was laid out to determine which constituent of the spray was causing the effect. The Toxaphene constituent gave the most severe symptoms, namely yellowing and curling of the leaves and bracts. With age the leaves lost the yellow appearance and became leathery and shiny. A boll analysis was undertaken on plants from each treatment to determine whether the visible damage to leaves had any effect on boll formation. The main differences observed were between the boll numbers per plant and lint index. Boll numbers were a function of the efficiency of the insecticides and lint index varied inversely with boll number. There appeared to be no evidence of a phytotoxic effect on yield, the variation of lint index with boll number being adequately accounted for as a consequence of compensation within the plant. It is concluded that the phytotoxic symptoms produced by the frequent insecticidal applications used in the crop loss experiment can be regarded as having no important effect in reducing the increment obtained from the treated plots.

Heliothis armigera Investigations.

Studies of populations of *Heliothis armigera* Hbn. were continued for the second year on farm crops that are attractive to this pest. They included maize, groundnuts, beans, sunflower and cotton. These crops provided a range of hosts over a large part of the year, and the study therefore yielded substantial knowledge of the bollworm's activity throughout the year. The size of the populations was dependent on the attractiveness of the crop at the time to the ovipositing moth and on the incidence of mortality during the egg and larval stages. A higher number of eggs was recorded on maize than on sunflower but the proportion of larvae surviving was lower. It is suggested that the difference in feeding area available in the two crops is the reason for this, the form of the maize ear encouraging the cannibalism common in larvae of *H. armigera.* On all the crops examined, oviposition commenced before flowering began. It built up until the maximum coincided with maximum flowering and dropped immediately the flowers died.

Laboratory tests have been conducted on larvae reared in culture to determine the effectiveness of the nuclear polyhedral virus disease reported in the 1954-5 Progress Report. Food sprayed with suspensions of diseased larvae is highly infective, particularly to the younger instars, death from virus disease occurring after an incubation period of from 3 to 10 days. The incubation period is dependent on the age of the larva, with a shorter period occurring in the younger instars. Advances have been made in isolating the polyhedra from diseased

larvae, thereby simplifying the estimation of the polyhedral concentrations which is necessary prior to conducting field trials. As a large scale measure, however, the use of the virus will be limited by difficulties in the production of the virus in sufficient quantities. *H. armigera* is at present the only known host, and its larvae are not easy to rear in large quantities, owing to its highly cannibalistic habit.

Plant Pathology

BY

G. M. WICKENS AND C. LOGAN.

Bacterial Blight (*Xanthomonas malvacearum*).

On the station, the season was similar to the previous one in being generally unfavourable to natural development of bacterial blight. These conditions again operated with particular force, and with special perversity, in a continuation of the previous year's experiment designed to determine the influence of bacterial blight on yield. As before, the experiment was laid down on three well separated sites. On one of them the experimental plots (of the highly resistant Albar 49, the susceptible BP52/S9, and NC54, in 5 randomised blocks) were grown from seed treated with an organic mercurial dust; on the other two the seed was inoculated with *X. malvacearum*; and in one of these latter the plants were subjected, on three occasions, to leaf spray inoculation. Every plot was within a plot of untreated Albar 49, as a control for all fertility factors other than *X. malvacearum* attack. Seed inoculation led to abnormally low incidence of primary infection (the highest incidence of main stem lesions in any plot at 12 weeks was 4·4%), and secondary infections of stems and bolls were negligible. The leaf spray inoculations, applied at 5, 8 and 11 weeks after planting, although inducing severe disease on the leaves susceptible at the times of application, all failed to lead to any material incidence of stem or boll attack. The yield data failed to indicate any adverse effect of the inoculations on yield.

Somewhat different conditions, especially in relation to boll infection, occurred in patches of a 600 ft. strip planted only one day later on another part of the station, with acid-treated and organic mercury dusted seed of NC55/Q at the same 3 ft. × 1 ft. spacing. In this, 5 foci of primary infection were deliberately introduced, and 2 others, unpremeditated, occurred (a primary infection rate, from the acid-treated and mercury dusted seed, of only 0·01%). Occurrence of bacterial blight in all phases was mapped at intervals plant by plant, at first over the whole strip, and later in plots selected to cover the range of disease intensity up till then recorded.

Early leaf infection (up to $10\frac{1}{2}$ weeks from planting), was sporadic and showed no particular positional relationship with earlier infections. There was a strong tendency for both stem and boll infections to occur on plants that had shown early leaf infections, rather than on plants that had not. Plots with low early leaf infections developed a low incidence of stem and boll infection; relatively high stem and boll infection occurred only in plots with relatively high early leaf infection, but not in all of them (Table 10).

Table 10.

Plot No.	*Percentage of plants with*		
	Early leaf infection.	*Stem infection.*	*Boll infection.*
2	0·0	0·5	0·0
16	0·9	0·0	1·4
9	1·8	0·0	4·1
7	2·3	0·0	0·9
17	2·5	1·0	3·9
5	2·8	0·0	3·2
8	7·7	1·0	9·1
3	13·9	1·5	0·5
6	18·3	3·4	16·3
22	31·1	5·0	21·0
4	37·4	0·5	3·8
18	55·5	7·3	45·1

The intensity of leaf attack was throughout only slight; in no single plant were more than one or two leaves affected. In the light of this the rather high incidence of boll infections in some plots (in plot 18, 177 of the 1,098 bolls were infected) is notable, though not surprising as such occurrences have commonly been observed in many parts of Africa. What is surprising is the almost complete absence of boll infections in an almost exactly contemporaneous crop, subjected to repeated severe leaf infection as reported above. Evidently, rather critical conditions are necessary for natural occurrence of boll infection. These are at present unknown.

Further tests of methods for determining relative reaction to seed, leaf, stem and boll inoculation were made in 2 sets of material; a group of Nigerian strains, with some local strains including the known standards Albar 49, BAR 7/8, and BP52/S9, and a group of strains from the Sudan also with local standards for comparison. The Sudan strains included a number of combinations of the resistance genes B_2, B_3 and B_{6m}, or none of them, in both *hirsutum* and *barbadense* cottons. Each group of 16 strains was planted in 2 balanced lattices of 5 replications, for one of which the seed was treated with organic mercurial dust (so that for later leaf, stem and boll inoculations, earlier elimination of highly susceptible plants through primary infection from the seed was avoided), and for the other the seed was inoculated with *X. malvacearum* in the standard manner.

The local strains reacted in accord with previous experience. Of the Nigerian strains, 26C/49130-21 proved susceptible to all phases of attack, and 26C/49160-23 BCP showed evidence of a useful measure of general resistance, in confirmation of the results of the previous season. The 26C/479-25 group also again showed stem resistance.

In the experiments involving the various genotypes from the Sudan, all strains carrying B_2B_{6m} (Domains Sakel B_2B_{6m}, X1730A B_2B_{6m} and $B_2B_3B_{6m}$, and BP52 B_2B_{6m}) showed virtual immunity to seed, leaf and stem inoculation. All except BP52 B_2B_{6m} also showed very high boll resistance; in the latter, however, although some degree of boll resistance was indicated by rather rapid drying of the lesions, the lesions developed to considerable size and damage to boll and lint development occurred.

Neither on Domains Sakel nor on X1730A did the gene combination B_2B_3 show evidence of conferring resistance to any phase of the disease. These *barbadenses,* with and without B_2B_3, were much more susceptible to stem attack than the most susceptible *hirsutums.* Among the latter, previous results were confirmed in the failure of B_2 to confer any material resistance, in B_2B_3 conferring good resistance to (or escape from) primary cotyledon infections but little if any stem resistance and no boll resistance, and in Albar 49 having high resistance to all phases, amounting to virtual immunity to stem and boll attack. B_3 alone had the same effect as B_2B_3 in leading to a low incidence of primary cotyledon infection but no other material resistance; indeed boll susceptibility was particularly high.

In subsidiary experiments, Stoneville 5 and Bambesa 197 (from the northern cotton zones of the Belgian Congo) developed in consequence of seed inoculation a higher incidence of primary infection, and more severe subsequent leaf and stem attack, than SUS 7/2.

All lines of a Menoufi stock supplied by C. H. Brown (see Brown 1955) were highly susceptible to primary infection from seed inoculation. Primary vascular infection (Wickens, 1956) was particularly prominent, and this may be of special significance in the arid climate of Morocco.

Inoculations for determination of boll susceptibility, in the experiments involving the Nigerian and Sudan strains, were made by applying inoculum to the 2-day old bolls by means of a fine paint brush, instead of by atomiser. Three to four weeks later the inoculated bolls were collected, and detailed records of the characteristics of the lesions were made. This work was largely undertaken by H. M. Parker, as part of his studies here before taking up his appointment in Nigeria. The most important characteristics, as indices of susceptibility, appeared to be size as measured by greatest diameter, rate of drying, and rate of penetration of carpel wall.

Although this method has given good results in the comparative testing of groups of plants, and has the special merit that infections occur in a close approximation to the natural manner, there are difficulties in its application to single plants. Breeding and selection work requires, for determination of inherent boll resistance in single plants, a less laborious method applicable to older bolls, relatively uncritical of boll age, that will lead to infections without escapes, and provide lesions with a readily measurable characteristic closely related to susceptibility under conditions of natural infection. Much progress has been made in the use of a modified needle prick technique to this end. Data on boll resistance given in the report of the Plant Breeding section were obtained by this means.

Verticillium Wilt (*Verticillium dahliae*).

A more extended and detailed study of the movement of *Verticillium dahliae* in plants wound-inoculated at stem base, in the susceptible U4/8161 and the tolerant B181, fully confirmed previous observations of a rapid and extensive longitudinal movement in both varieties before any symptoms appeared. The plants were inoculated at about 10 weeks from planting, and the first barely detectable external symptoms of disease were noted on the 11th day. Within 48 hours of inoculation the fungus was detected (by isolation) in the xylem of the main stem up to about half its length, a distance of about 10 inches, in both varieties. In two plants of U4/8161 it had extended 15 inches in the main stem, and in one plant it had extended 19 inches into a leaf. By the 6th day the fungus was present almost throughout the main stem, and in most of the main stem petioles and leaves, being detected in both varieties at points up to 30 inches from the site of inoculation. Copious development of the fungus in infected leaves kept under humid conditions was again commonly observed, indicating their probable importance in increasing the inoculum potential in the soil.

Plant Breeding

BY

H. L. MANNING, R. C. FAULKNER AND D. E. B. KIBUKAMUSOKE.

BP52 Modal Bulk.

Estimates of lint yields per acre are available for 1MB, 2MB and 5MB in the Modal Bulk series from a large number of variety trials conducted over a wide range of environmental conditions. Similar data for 7MB and 8MB were available only from small scale trials at a single locality. In some of these trials comparisons were made with the commercial BP52—designated "local BP52"—and in others against

K51, the improved BP52 made in 1944 at Kawanda. The local may be taken as a representative sample of the original and has, therefore, been equated to 100 per cent. K51 is discussed in a later section, where it is shown that its superiority over local is probably of the order of 3·3 per cent. of original.

A linear regression was calculated for the increments of the various modal bulks in time as a percentage and is given by

$$102.321 + 2.558X$$

where X is the specific modal bulk. Thus 5MB is expected to be 15·1 per cent. better than local. In fact this may be checked against K51 from data of 1953-4. Here 5MB over 30 replications was 10·4 per cent. better than K51. If a superiority of 3·3 per cent for K51 is accepted, then 5MB in fact was 13·7 per cent. better than local. In this report 7MB, which has been used by several sections, is shown by the regression equation to be about 20 per cent. better than local BP52.

In view of the yield improvement which has been effected in successive modal bulks, it is of interest to examine the selection differentials which have been exercised for lint yield, when selecting successively in the traits lint index, seed weight and mean maximum halo length. In addition, some account must be taken of the selection differential resulting from the effect of the disproportionately higher number of seeds contributed by the higher yielding plants. The selection differential as used here is defined as the mean lint yield of plants chosen to be parents compared with the mean of the entire population in which they were grown. These data are summarised in Table 11.

Table 11.

Selection differentials for yield in successive modal bulks. Annual and cumulative values as percentages.

	Lint per Plant		*Seed Number*		*Total*	
	Annual	*Cum.*	*Annual*	*Cum.*	*Annual*	*Cum.*
1MB	7·8	—	24·4	—	32·2	—
2MB	3·9	11·7	7·3	31·7	11·2	43·4
3MB	3·1	14·8	10·3	42·0	13·4	56·8
4MB	0·0	14·8	12·5	54·5	12·5	69·3
5MB	1·2	16·0	10·5	65·0	11·7	81·0
6MB	6·2	22·2	23·6	88·6	29·8	110·8
7MB	6·3	28·5	8·6	97·2	14·9	125·7
8MB	1·7	30·2	6·4	103·6	8·1	133·8
9MB	4·6	34·8	6·8	110·4	11·4	145·2
Means	3·9		12·3		16·1	

The average total annual selection differential of about 16 per cent. may be related to realised advance in yield to derive an estimate of its heritability. Thus from the regression equation earlier, it was shown

that over the period of 8 years yield improvement was at the rate of 2·6 per cent. per annum. This suggests that the average value for heritability would be of the order of 0·16. Such a figure is entirely consistent with the expectation of residual heterozygosity from open pollinated material in which out-crossing may easily occur.

Changes in mean values for traits over the 8 seasons are also of interest. The greatest response to selection has been recorded with mean maximum halo length. The length of the original or 0MB was 30·3 mms. and that for 6MB was 34·9 mms. Since the sixth generation length change has been negligible. Both lint index and seed weight have shown slight decreases and there has been an overall reduction in ginning out-turn.

BP52 Progeny Rows.

Forty-nine progenies were grown in a 7 × 7 lattice square. These 49, with an additional 19, were also grown in adjacent non-replicated rows. Within these sister plants single plant selections are made, the direction of selection being determined from the selection index based on performance in the replicated trial. The gain in experimental efficiency due to row and column adjustment was small, and the data were analysed in randomised complete block arrangements with 4 replications of plots of 1/726 acre at a spacing of 3 ft. × 2 ft.

The selection index was calculated on the basis of bolls per plant, seeds per boll and lint per seed. The method of estimating bolls per plant was changed somewhat. An index was calculated directly from lint per plant divided by the product of seeds per boll and lint per seed. This bolling index may be considered as realised bolls and the product of the three traits may be said to measure yield exactly. The means, phenotypic importance and heritabilities of the three traits and yield itself were:

	X_1 *Bolling Index*	X_2 *Seeds/Boll*	X_3 *Lint/Seed*	X_w *Lint/Plant*
Means	15·55	29·62	0·493	227
$\beta Y_i.jk$	0·909	0·382	0·483	—
g^2	0·420	0·085	0·269	0·335

Both the phenotypic and the genotypic importance of number of bolls per plant are apparent from these data, and the selection index in this season has consequently been heavily weighted in favour of the trait. The fact that these heritabilities are based on differences between progenies in strains emphasises the extent to which heterozygosity has persisted in this inbred material. At the same time since selection is practised between as well as within progenies, expected genetic advance in yield must be estimated somewhat circuitously. Thus the

b-coefficients are estimated on the basis of grand-parental heterozygosity and these in turn are applied to all progeny genetic covariances. Also the selection differential was estimated directly from the proportion retained in the selection index rather than the theoretical value of z/q.

Genetic advance indicated by saving 12 progenies is expected to be about 4·2 per cent. The cumulative expected genetic advance after 8 generations of selection would thus be of the order of 46 per cent. over the original material of 1947-8. Moreover, with the heritabilities shown above, it is evident that continued selection within at least three of the characters is still likely to be worth while. It is shown below that the major part of the calculated advance, up to the sixth generation, has been realised in large scale field trials.

So far no direct weighting for bacterial blight resistance has been used in the selection index. This year the Plant Pathologists introduced a boll inoculation technique and these data were analysed with a view to estimating the importance of boll lesion resistance in improving the efficiency of the selection index. Taking one boll from each of 20 to 30 plants in each progeny, it was possible to estimate the mean lesion size for each progeny. A frequency distribution of 68 progeny means is given below.

Mid-x	2·7	3·2	3·7	4·2	4·7	5·2	5·7	6·2	6·7	7·2
Frequency	6	6	8	17	12	12	4	1	1	1

Of the quite considerable range of variation it is of interest to note that the strain value of seven progenies selected in non-replicated rows for main stem lesion resistance averaged 3·3, compared with the overall mean of 4·4. Some of these have been isolated by using the main stem inoculation technique. Also, it was observed that the C(50)20 derivatives, with an average of 3·4, were of the same order of resistance. This confirms the inference made in the 1953-4 report that C(50)20 had fairly high boll lesion resistance. Moreover, since no conscious selection for resistance had been practised in the C(50)20 material it would appear that a degree of resistance has been built up indirectly through other factors in the selection index. It is, therefore, not surprising that the inclusion of boll lesion resistance as an additional trait in the index for this past season gave no improvement.

BP52 Progeny Bulks Trials.

Small bulks trials, which will in future be designated progeny bulks trials, were conducted under 10 environments at each of which there were 3 replications, with the current modal bulk as control. For the 1955-6 season the overall mean value of the six C(54) progeny bulks was 131·0 per cent. compared with the value of 120·2 per cent. for 7MB. In previous seasons, when the cropping capacity of the modal bulks

relative to local BP52 was uncertain, it was difficult to assess accurately the real advance of the progeny bulks. Now that the yield improvement in the successive modal bulks has been demonstrated, these differences can be accepted with confidence.

Comparisons between the expected genetic advance, calculated from the replicated progeny row selection index, and that actually achieved in progeny bulks trials are of considerable interest. For the C(54) series the expected advance was calculated at 41·5 per cent. and, as shown above, that actually achieved was 31·0 per cent. At the same time it should be pointed out that the larger value was estimated on the basis of a single favourable experiment station environment. By contrast the 31·0 per cent. was that realized from very much larger plots (1/50 acre), grown under 10 environments, made up of early and late plantings at each of five rather diverse localities. An improvement, under a wide range of field conditions, of some 30 per cent. resulting from 7 generations of selection may be considered to be a satisfactory achievement.

In these same trials the multiline strain NC54, which was a mechanical mixture of C(51) and C(52) series, gave a yield equivalent to 129·8 per cent. of the standard. This value is in close agreement with an independent assessment of this strain grown in district variety trials both in 1954-5 and 1955-6 and provides a valuable link between separate stages of the breeding work.

District Variety Trials.

The first of the multiline strains, NC54, has now reached the first stage of seed multiplication for the BP52 area. A second, NC55, and its close relative NC55/Q in which stringent line quality selection was practised, have also now been issued. To assess the actual yield improvement of these Namulonge selections of BP52 in district variety trials, trials over 10 seasons were examined. First, it was necessary to estimate the yield advance of selections made by the Department of Agriculture since some of these have been used as control; then it was desirable to estimate the advance of the Namulonge selections compared with the best of these.

Four of the most important selections made by the Department of Agriculture, BP52B, BC66, B181 and S47, were adequately tested during the seasons 1946-7 to 1949-50. Considering all trials, irrespective of their experimental precision, it was observed that BP52B (subsequently designated K51) yielded 100·5 per cent., BC66 (subsequently designated BP52/6) 98·1 per cent., B181 101·9 per cent. and S47 99·7 per cent., of the commercial or local BP52. These mean values were clearly inconsistent with the observed improvement of these selections demonstrated at the experiment stations of the Department

of Agriculture, where trials of reasonably high precision are conducted. Moreover, a comparison of B181 and BP52 (Manning Prog. Rep. from Expt. Stations, 1946-47) showed that the former outyielded local BP52 by more than 4 per cent., except under the most unfavourable growing conditions. The question then arises as to how best can these yield data be treated to give a fair estimate of cropping capacity applicable to the whole commercial area.

Taking first the coefficients of variation of 124 trials with plot size 1/66 acre in 5 × 5 Latin squares, the grouping is as follows:

<5·0%	5·1—10·0	10·1—15·0	15·1—20·0	> 20·1	Total
2	35	39	26	22	124

These data indicate that about 60 per cent. of the trials were reasonably precise; that is, with cov. $\leq$ 15·0 per cent. In fact the reality of differences was demonstrable in less than half of the trials grown during this period.

Examination of these trials separately reveals that in general, major or sub-stations, such as Bukalasa, Namulonge, Kalagala and Namyoya, enjoy high precision. A middle group which includes Kawanda, Bukomero, Bulindi, Kakumiro and Kisagazi, sometimes have coefficients of variation of less than 15 per cent. The remainder, Nkozi, Mukono, Kabasanda and Kyanamukaka, all have mean values of the coefficient of variation greater than 16·0 per cent. The worst trial is at Kabasanda. This site has the most satisfactory rainfall probability in respect of crop water requirements, but suffers from two defects. These are firstly, a fairly steep slope on which, so far, no effective water conservation has been practised and, secondly, the existence of a condition known locally as "lunyu". It is sufficient to state that with plot yields varying in this past season from 7 to 1,063 at Kyanamukaka, from 165 to 1,155 at Kabasanda, from 119 to 1,115 at Bukomero and from 125 to 521 at Galiraya, all in lb. seed cotton per acre, varietal means can be seriously distorted.

One method of evaluating the trials is to weight means inversely according to the separate standard errors of the trials. Even this assumes some reasonable homogeneity of variance. Another approach would be to take an arbitrary estimate of precision and ignore all trials say with coefficients of variation in excess of 15·0 per cent. Perhaps the most satisfactory method is to include only those trials in which the error variance satisfies a test of homogeneity. In fact, only those trials in which the reality of differences could be demonstrated were used. These data summarized over 10 seasons, together with means of all trials ignoring precision, are summarized in Table 12.

Table 12 (A) shows the anomalies in regard to the original selections to which reference has already been made. The apparent depression of

TABLE 12.

YIELD IMPROVEMENT OF BP52 MATERIAL RELATIVE TO LOCAL BP52.

Season	No. of trials	Local BP52	Original selections				Modal bulk				Multi-line strains				Separate progeny bulks								
			K51	BP52/6	B181	S47	1MB	2MB	5MB	6MB	NC51	NC54	NC55	NC55Q	C(48)4	C(48)12	C(49)3	C(50)17	C(50)20	C(51)19	C(51)22	C(52)16	C(52)18
(A) ALL TRIALS (IGNORING PRECISION AND HOMOGENEITY OF ERROR VARIANCE).																							
1946-7	11	100	—	—	107·7	—																	
1947-8	10	100	97·9	94·0	98·3	95·8																	
1948-9	12	100	103·2	99·4	101·5	102·6																	
1949-50	14	—	103·3*	97·4	100·0	100·6	101·0																
1950-1	13	—	103·3*	—	—	99·8	—	100·6															
1951-2	13	—	103·3*	—	—	—	—	—			108·0				95·9	107·3							
1952-3	14	—	103·3*	—	—	—	—	—			103·7				—	112·5	104·9						
1953-4	16	—	103·3*	97·9	—	—	—	—	113·7		—				—	—	—	101·7	112·3				
1954-5	13	—	—	—	—	—	—	—	—	117·7*	—	120·5			—	—	—	—	124·0	111·7	122·5		
1955-6	14	100	—	101·7	—	—	—	—	—	—	—	117·5	115·2	115·8	—	—	—	—	121·0	—	—	124·6	123·2
Means	13·0	100	103·3*	98·1	101·9	99·7	101·0	100·6	113·7	117·7*	105·9	119·0	115·2	115·8	95·9	109·9	104·9	101·7	119·1	111·7	122·5	124·6	123·2
(B) ONLY TRIALS WHERE VARIETAL DIFFERENCES STATISTICALLY SIGNIFICANT.																							
1946-7	7	100	—	—	106·6	—																	
1947-8	5	100	99·4	97·5	107·3	107·3																	
1948-9	5	100	107·2	104·9	106·7	106·7																	
1949-50	4	—	103·3*	98·8	101·5	98·3	104·7																
1950-1	5	—	103·3*	—	—	105·9	—	108·7															
1951-2	6	—	103·3*	—	—	—	—	—			108·3				100·9	118·7							
1952-3	4	—	103·3*	—	—	—	—	—			108·0				—	117·6	106·2						
1953-4	11	—	103·3*	98·3	—	—	—	—	113·7		—				—	—	—	112·4	125·8				
1954-5	3	—	—	—	—	—	—	—	—	117·7*	—	127·4			—	—	—	—	130·1	115·2	128·3		
1955-6	7	100	—	104·3	—	—	—	—	—	—	—	126·4	128·5	125·4	—	—	—	—	130·3	—	—	129·8	133·9
Means	5·7	100	103·3*	100·8	105·5	104·6	104·7	108·7	113·7	117·7*	108·2	126·9	128·5	125·4	100·9	118·1	106·2	112·4	128·1	115·2	128·3	129·8	133·9

*Estimated (See Text)

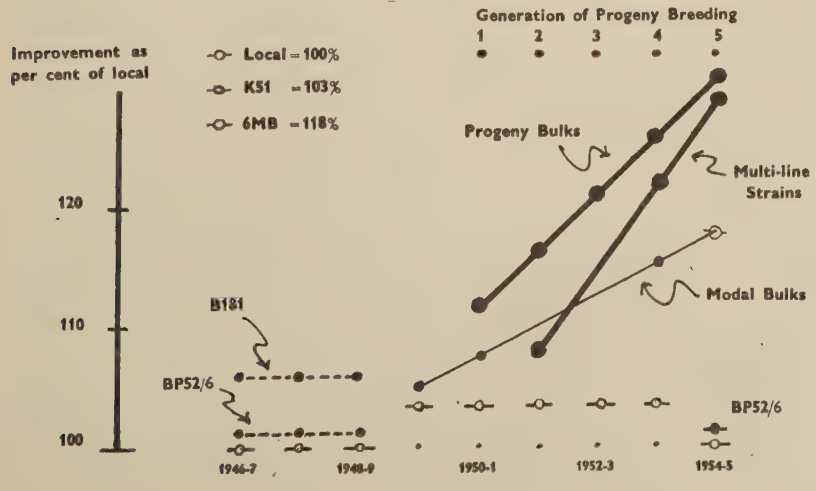
1·9 per cent. shown for BP52/6 does the variety less than justice, and neither B181 nor S47 showed the improvement expected of them. In Table 12 (B) are summarized only those trials in which the reality of differences could be demonstrated. Taking K51, the mean value for two seasons against local BP52 indicated an advance of 3·3 per cent. This modest improvement has, therefore, been assumed wherever it has been necessary to use K51 as a standard. Agreement between seasons both for B181 and S47 is considerably better on this method of grouping and, indeed, is more consistent with the known performance of these varieties.

The progress achieved as a result of introducing Namulonge BP52 selections may now be considered. Progeny row breeding was initiated during the 1948-9 season so that the first progeny bulks could only be tested in 1949-50. Similarly the variety trial stage was not possible until 1950-1. The actual generation of selection under test is, however, easily determined from the nomenclature beginning with the C(48) progenies in 1948-9. Thus the C(52) series is from the fifth generation of selection. In addition to the progeny bulks, a number of multiline strains were tested. So far three such multiline strains have been constituted and their strain components are given in the Appendix.

Table 12 (B) shows that the C(52) progeny bulks gave a yield increment of nearly 34 per cent. The annual advance thus represented for the best is in good agreement with the expectation from the selection index. The advance from the multiline strains is rather smaller. These contrasts are more readily apparent in Fig. 6 where the relevant yield data from Table 12 (B) are presented diagrammatically.

FIGURE 6

Yield Improvement of BP52 Selections over Controls in District Variety Trials



The overall advance of over 30 per cent. for progeny bulks is clearly shown in Fig. 6. The rather smaller but still satisfactory increase of the multiline strains is also shown. An important feature of this diagram is the position of the 6MB control in the 1954-5 season. This was estimated from a linear regression in an earlier section to be about 117·7 per cent. On this assumption NC54 in that season was expected to be 127·4 per cent. The fact that NC54 grown in 1955-6 against the actual local gave 126·4 is adequate confirmation of the relative position of 6MB. Moreover, the good agreement between the C(50)20 grown in three seasons, in one of which 6MB was the control, provides further substantiation if indeed this were needed. There can be little doubt that the predicted advances for these Namulonge strains are in fact realised.

Two important aspects of the breeding programme as a whole may now be considered. The first of these relates to the choice of trials with high precision for predicting yield advance. Since these more often than not are in the areas of favourable growing conditions, it may be argued that there will be a tendency to produce strains whose full potential is only realised in a favourable environment. This was not so, however, and the order of yield in the trials with a low precision does not differ in any important respect from that in trials of high reliability. Thus it is fair to say that those variety trial centres that have given the most useful information may be accepted as indicative of varietal behaviour over the area as a whole.

The second aspect to be considered is the behaviour of the multiline strains. So far, only material grown from mechanical mixtures of seed has been tested, and the effect of interbreeding of the component lines remains uncertain. The behaviour of these mixtures has been consistently rather less good than that of the best lines, and the very limited heterosis effects realised in cotton breeding are unlikely to improve the performance of later generations of multiline strains beyond that of the best single lines. Multiline mixtures have in the past been used to even out minor defects in their component single lines, but with the elimination of these defects as the breeding project advances, it now appears that the issue of single line strains will be advantageous in the future.

Hitherto, in considering BP52 material for issue, performance under poor conditions has been regarded as of primary importance. The agricultural practices that will ensure good crops in the BP52 area are now well known, and there is therefore little excuse for a policy of breeding good cotton for a poor farmer. In any case, the variety × locality interaction in the BP52 material has been shown to be small, and it is, therefore, proposed in future to devote the breeding effort to the production of the best cottons for good farming conditions.

Yield Trials with Local Issues of BP52.

Throughout the BP52 area there has been an increase in the proportion of "black seeds" during recent years. The term "black seeds" is used locally to describe all types of seed with less than the normal full coat of fuzz. Some of these types also have less than the normal full coat of lint and it has been suggested that the increase in black seeds has caused a fall in ginning out-turn. To test this possibility, 13 seed samples taken from ginneries issuing seed in the areas around the 13 district variety trial centres were planted in a randomised block trial with 3 replications and a plot size of 1/90th acre, using 7MB as control. The proportion of black seeds in the samples before planting ranged from 10-20% with a general mean of 14·2%. In 7MB the proportion was less than 1%. The mean yield of the trial was 269 lb. of lint per acre. With a coefficient of variation of 14% the precision of the trial was too low to detect any difference between issues. The proportions of fuzzy, semi-fuzzy, tufted and naked seeds were determined for each plot.

	Mean of 13 local issues	*7MB*
Fuzzy	40·4	95·5
Semi-fuzzy	44·4	3·8
Tufted and Naked ("black")	15·2	0·7

Differences between local issues were not significant. The correlation coefficient between black seeds and ginning out-turn was $r = -0{\cdot}43$, significant at 0·001. From the regression equation it appears that an increase of 10% in black seeds was associated with a decrease of 0·4 in ginning out-turn.

Further evidence on the relation between black seeds and ginning out-turn was obtained from another trial in which 5 plots of black seeds and 3 plots of fuzzy seeds were planted, the two groups being obtained from the ginnery samples used in the previous trial. At the end of the season ginning out-turn, 100 seed wt. and black seed % were determined for each plot. Results are given in Table 13.

Table 13.

Seed cotton characters of black and fuzzy seed plots.

	Means of 5 Black plots	*Means of 3 Fuzzy plots*	
Ginning out-turn percent	31·3	32·6	Significant at 0·01
100 seed wt.	9·3	9·6	Not significant
Fuzzy seeds %	29·6	91·9	
Black seeds %	70·4	9·1	

A comparison of black seed % with ginning out-turn gave a correlation coefficient of −0·79, significant at 0·01. The two trials, therefore, agreed in showing a significant relationship between low ginning out-turn and high black seed %.

Albar and Albar Hybrids.

Albar 51, the main source of bacterial blight resistance used at Namulonge, comprises a large number of strains having a high degree of resistance to the main stem phase of the disease, while retaining a wide range of variability in yield and in lint and seed characters. Since 1952 a programme of crossing and backcrossing of Albar 51 strains with UP strains has been followed in an attempt to combine the bacterial blight resistance of Albar with the jassid resistance and lint quality of the UP stocks. The strains thus obtained (known as UPA strains) comprise 7 crosses, 7 backcrosses and 6 second backcrosses. The results of last season's spinning tests on Albar and UPA are given in Table 14. The results of tests on BP52 strains are included for purposes of comparison.

Table 14.

Spinning test data on Albar 51 and UPA strains.

	Effective length		Maturity ratio		Std. fibre weight		Count strength product	
	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
Albar 51 (12 strains)	39·6	4·3	0·93	8·3	195	9·2	2133	11·5
UPA (12 strains)	41·6	2·2	0·82	2·7	183	4·7	2187	3·1
BP52 (20 strains)	38·4	2·1	0·93	2·4	168	2·3	2258	3·1

In the Albar group, effective length and maturity ratio compared favourably with BP52. Although the mean value for standard fibre weight was higher, and for count strength product was lower than in BP52, the greater range of variability in the Albar group should make possible considerable improvement by selection. In the UPA group the effective lengths were very satisfactory but other characters were inferior to BP52, and their range of variability was only slightly greater than in BP52. It would, therefore, appear from these results that there is greater scope for improvement by selection in Albar than in UPA.

Nineteen small bulks and sixty-two progeny rows of UPA, and sixty-seven single row bulks of Albar were planted on June 6th. All plants were inoculated with bacterial blight in the main stem 10 weeks later, and susceptible plants were uprooted. Resistant plants were selfed for the remainder of the flowering season. In the Albar group only one bulk had fewer than 80% resistant plants and 37 bulks contained no

susceptibles. There was considerable variation in the UPA group and much susceptible material was eliminated. As it is intended to test UPA strains in the Eastern and Northern Provinces of Uganda, where jassid attack may be more severe than in the BP52 area, selection was exercised for hairiness, and about 25% of the plants were discarded on poor leaf-hair.

Samples of open pollinated bolls were taken from all UPA progeny rows and Albar single row bulks. Ginning out-turn, 100 seed weight, lint index and seed coat nep damage were measured for each sample, and estimates of seeds per boll were made. About $\frac{1}{3}$ of the rows were eliminated on the data from these bulk samples and the remainder were picked as single plants. Other single plants were taken from the UPA bulks, giving a total of 456 UPA and 430 Albar selections. Lint length, ginning out-turn, 100 seed weight, lint index and nep damage were determined for each selection, and frequency arrays plotted for each character in UPA and in Albar. Means and coefficients of variation for each character are given in Table 15.

Table 15.

Seed cotton characters in Albar and UPA selections.

	Albar (*n*=430)		*UPA* (*n*=456)	
	Mean	*c.v.*	*Mean*	*c.v.*
Ginning out-turn	36.3	5·8	35·5	5·3
100-seed weight	9·5	10·9	9·8	10·4
Lint index	5·4	11·8	5·4	12·8
Lint length	32·3	5·9	33·1	5·6
Nep damage %*	13·5	17·6	14·0	4·2

*Adjusted for skewness on a square root transformation.

Correlation surfaces were plotted for various pairs of characters and it was shown that there were no strong negative correlations. Selections were then made, setting the following minimum standards for each character:

100 seed wt.	10·0 gm.	Lint length	33·0 mm.
Lint index	5·0 gm.	Nep damage	15%

Of the selections thus obtained, only 48 UPA and Albar selections had sufficient selfed seed to plant a replicated trial. Airflow tests were made on each selection in this group to determine the relative maturity of the chalazal lint and the remainder, selections with high Rm-Ch values being discarded. 23 UPA selections and 23 Albar selections were finally retained for next season's progeny rows. Mean values and selection differentials for each character are given in Table 16.

TABLE 16.

COMPARISON OF ORIGINAL AND FINAL SELECTIONS.

	Albar				*UPA*			
	Original	*Final*	*Selection*	*Differential*	*Original*	*Final*	*Selection*	*Differential*
			Actual	*% Original Mean*			*Actual*	*% Original Mean*
No. of Selections	430	23	—	—	456	23	—	—
Ginning out-turn	36·3	36·3	—	—	35·3	36·2	0·37	1·0
100 seed weight	9·5	10·0	0·48	5·1	9·8	10·5	0·67	6·8
Lint index	5·4	5·7	0·47	8·7	5·4	6·0	0·90	16·7
Lint length	32·3	33·8	0·78	2·4	33·1	34·1	0·54	1·6
Nep damage	13·5	13·0	0·21	1·6	14·0	16·6	−4·40	−31·4

Airflow tests were also made on those selections with small amounts of selfed seed, and the best were finally retained to plant additional non-replicated progeny rows.

Standard UPA and Albar bulks which will serve as controls in the replicated progeny rows were made by mixing equal numbers of seeds from all single plants in the UPA group and in the Albar group. These will be maintained annually by taking equal numbers of seeds of each plant grown, to provide a standard of comparison for the selected stocks.

Comparison of Namulonge Breeding Stocks.

A yield trial was planted on June 4th to compare a range of strains from all breeding stocks now available at Namulonge. The design used was a 7 × 7 lattice square with 4 replications and a plot size = 1/100 acre. The 49 strains were made up as follows:

Albar 51	31	
UP	3	
UPA	6	
BP52, [C(50),20, C(53)9, C(52)16]	3	7
BP52 [selected for bacterial blight resistance]	3	
Control [BP52.7MB]	1	
Lubaga strain	1	2
Lubaga × Albar strain	1	

The trial was efficient, giving a standard error of 30·2 and a coefficient of variation of 3·3%. The information from the trial relative to a randomised block analysis was 104·9%. Differences between strains were highly significant (P = 0·001). The means and coefficients of variation for lint yield and lint index are given for each group in Table 17.

Table 17.

Lint yield and lint index in a comparison of Namulonge stocks.

	Lint Yield		*Lint Index*	
	Mean	*c.v.*	*Mean*	*c.v.*
Albar (31 strains)	317·0	22·4	5·6	9·6
UP (3 strains)	308·8	7·1	5·0	2·0
UPA (6 strains)	304·6	9·1	5·3	2·5
BP52 (7 strains)	326·6	5·8	4·9	3·3
Lubaga (2 strains)	285·8	14·5	4·9	7·1

The differences between the group mean yields were not statistically significant, but there were large differences in variability between strains within groups. The BP52 group was fairly uniform, whereas in the Albar group yields ranged from 175 to 425 lb. of lint per acre. The range of variability of lint index was also greater among the Albars than in any other group. The best Albars significantly outyielded the best of the BP52 strains in this trial, indicating a very useful yield potential under Namulonge conditions. No other group showed promise of

yielding material appreciably superior to BP52. Within the Lubaga group the crossing programme with Albar has produced a significant increase in yield but the best of the Lubaga × Albar strains were still significantly inferior to both BP52 and the best Albars.

Verticillium Wilt Resistance.

A bulk of resistant strains of B181 × BP50 was inoculated with *Verticillium* 10 weeks after planting and susceptible plants were discarded. The remainder were inoculated with bacterial blight in the main stem and again all susceptible plants were removed. As the bulk was well isolated from other cotton, no selfing was done and the open pollinated bolls were picked as a bulk.

All UPA strains and a few Albar 51 strains were grown as single row bulks and inoculated with *Verticillium* 10 weeks after planting. No resistant plants were found.

Lint Testing.

Routine quality tests were carried out through the season as set out in the 1954-55 Progress Report, and about 250 cotton samples have been examined since October 1955. Most of these samples were from the Plant Breeding Section, Namulonge, but samples from Tanganyika were also tested.

Data are being accumulated concerning the relative maturity of chalazal lint (Ch) and lint from the sides of the seed (Rm) with the object of studying the seasonal effects on them.

Changes in seed weights and lint indices which were observed in the previous seasons from early to late formed bolls in the same crop were observed once more in BP52.5MB, S47, and CL20. Data grouped into weekly flowering periods are given in Table 18. In seed weight

Table 18.

Effect of flowering date on seed cotton characters: three varieties.

Flowering Date	*Seed Weight*			*Lint Index*			*% Seed Coat Nep*		
	5MB	*S47*	*CL20*	*5MB*	*S47*	*CL20*	*5MB*	*S47*	*CL20*
2·9 – 8·9	12·2	—	—	6·5	—	—	28	—	—
9·9 –15·9	12·0	12·6	14·5	5·5	5·8	7·0	8	44	17
16·9 –22·9	11·7	11·8	13·6	5·1	5·5	6·3	9	44	12
23·9 –29·9	11·1	11·5	12·9	4·9	5·2	5·9	10	25	14
30·9 – 6·10	10·0	11·3	12·8	4·6	5·4	5·9	15	45	5
7·10–13·10	10·5	11·0	12·8	4·6	4·8	5·6	11	30	13
14·10–20·10	10·5	10·6	12·6	4·6	4·6	5·5	2	22	7
21·10–27·10	10·5	10·9	12·6	5·0	5·1	5·5	3	11	5
28·10– 3·11	10·0	10·4	12·3	4·8	4·9	5·5	6	20	3
4·11–10·11	10·0	10·2	12·7	5·0	5·2	6·2	9	21	7
11·11–17·11	10·0	10·4	11·5	5·0	5·6	5·7	7	24	5
18·11–24·11	10·4	—	—	5·1	—	—	13	—	—

early bolls gave high values and late bolls low figures in all varieties. In lint index, values tended to fall progressively with the advance of the season but rose again slightly at the end of the flowering season. Routine quality tests also were carried out on these groups. Seed coat nep counts fell through the season for all three varieties. There was no noticeable seasonal trend in Baer sorter diagrams. The airflow test indicated that a slight reduction in Rm-Ch values occurred, amounting to 0·15 in BP52.5MB, 0·10 in S47 and 0·20 in CL20 in favour of the late formed bolls.

Two multiline strains were put up in 1955 (see above). One (NC55) was constituted on the same criteria of yield and quality as in previous years, and the other (NC55/Q) was made up by including only those lines that were judged to be of high quality on the above quality tests, as well as giving good yields. It was hoped that in this way it would be possible to make an advance particularly in yarn appearance. At picking time, as soon as sufficient seed cotton had been ginned, a full bale each of NC54, NC55, and NC55/Q, together with a bale of Kawanda K51, was sent by air freight by the Lint Marketing Board to the Lancashire Cotton Corporation for spinning tests.

Thanks are due to the Lancashire Cotton Corporation for a comprehensive test carried out in a very short time. They reported that the carded yarns from NC55/Q were of excellent quality, and were not greatly inferior to combed. If this performance can be matched in bulk production, the competitive value of BP52 against Ashmouni will be much improved. In general, all the Namulonge multiline strains gave a yarn strength comparable with that of the control, and were superior in yarn appearance. Thus it is evident that the breeding system in force is improving quality steadily and the recently established lint testing system promises to provide a quality control on the breeding work of considerable precision.

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Appendix.

Key to Symbols and Abbreviations used in the Text.

Usually the number following a letter refers to the year in which the issue was made e.g. S47, Uk48, and NC54 were issued in 1947, 48, and 54 respectively. The notable exception is BP52.

Acala 29-4 Acala 29-6	*Verticillium* wilt resistant strains from the U.S.A.
Albar	Nigerian Allen (–Al) blackarm resistant (–bar) selections. Two series of selections were made independently, Albar 49 in 1949 and Albar 51 in 1951.
B	Bukalasa selections.
B181	Selections from Buganda local made in 1934 as being resistant to *Verticillium* wilt.
Bambesa 197	Belgian Congo strain.
BAR	Blackarm resistant.
BAR 12	This series comprises BP52 stocks to which major genes for blackarm resistance were transferred at Shambat.
BP	Bukalasa pedigree.
BP50	Selection from B37 ex Buganda local made in 1933 at Bukalasa.
BP52	Commercial variety in Uganda west of the Nile. Selected at Bukalasa in 1933 out of B42 ex Nyasaland Upland.
BP52/6	Selected by J. D. Jameson at Bukalasa out of B181 × $BP52^4$ to give BC66 in 1948 which became BP52/6 in 1953.
BP52/S9	A selection out of BP52 for great susceptibility to blackarm.
CL20	Selection made at Domira Bay, Nyasaland.
C(x)Y	Selections from BP52 at Namulonge by H. L. Manning. Progeny row number Y in year x.
26C series	Selections made at Samaru, Northern Nigeria.
Empire Derivative	Mixture of crosses of Empire (American commerical varieties).
Hybrid 330	Hybrid material of American Upland, Sea Island and Hopi Acala origin, selected for long staple.
K or KP	Kawanda (Agricultural Department Research Station) selections.
K51	Selection at Kawanda out of BP52 bulk previously known as BP52.B.
Lubaga	See Tanganyika.

MB	Modal Bulk—standard or control BP52 started at Namulonge in 1948/9 to give 1st generation or 1MB. 8th Generation in 1955/6 = 8MB. Often written BP52.8MB.
Menoufi	Egyptian variety received from C. H. Brown.
MU8	Indian Upland selected in Malwa by J. B. Hutchinson.
N	Selections made in Uganda out of Nyasaland Upland stock.
NC	Multiline strain selected at Namulonge out of BP52 for general distribution in BP52 area.
NC51	C(48)4 and C(48)12.
NC52	C(49)3, C(49)16, C(48)12, C(48)4, and 7MB } not issued.
NC53	No multiline strain made in this year.
NC54	C(50)20, C(50)17, C(51)22, and 5MB.—first to be released for multiplication.
NC55	C(52)16, C(52)18, C(50)20, C(51)22 and 6MB.
NC55/Q or BPQ	C(53)9, C(53)14, C(53)26, C(53)19 and 6MB. Selection for quality.
S	Serere selections 1940-49.
S47	BP50 grown at Serere was selected in 1945 to give S5302 which when bulked and issued in 1947 became S47.
Stoneville 5	U.S.A. strain brought in via the Belgian Congo.
SUS	Susceptible to blackarm.
Tanganyika 7/367	and related material: selections made at Lubaga and Ukiriguru from among the longer and finer derivatives of Lake Province stocks. Referred to as "Lubaga" in Plant Breeding report.
U	Barberton selection.
U4/8161	Selected from U4 at Barberton. Highly susceptible to *Verticillium* wilt.
Uk	Ukiriguru selection.
UP	MU8 × $BP52^2$.
UPA	Hybrid material from (MU8 × $BP52^2$) × Albar 51.
V135	St. Vincent (B.W.I.) selection of superfine Sea Island. Highly resistant to *Verticillium* wilt.

For key to symbols used for Sudan types see Sudan Progress Report.

Lint Quality.

SAFI	Swahili for clean cotton.
FIFI	Swahili for soiled, stained or substandard cotton.
FAQ	Fair average quality.
Ch	Air flow through standard plugs of chalazal lint.
Rm	Air flow through standard plugs of remaining lint.

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